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**Singleton, IV et al.**

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(54) **RENDERING A WEB APPLICATION IN A CLOUD SERVICE**

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(51) **Int. Cl.**

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| ***H04L 29/08*** | (2006.01) |
| ***H04L 12/24*** | (2006.01) |

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(58) **Field of Classification Search**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 9,311,457 | B1 * | 4/2016 | Thirthala | H04L 67/02 |
| 10,037,424 | B1 * | 7/2018 | Guenther | G06F 21/53 |
| 2010/0082813 | A1 * | 4/2010 | Li | H04L 67/16 709/226 |
| 2012/0317236 | A1 * | 12/2012 | Abdo | H04L 67/02 709/219 |
| 2014/0108496 | A1 * | 4/2014 | Heller | G06F 16/951 709/203 |
| 2015/0161277 | A1 * | 6/2015 | Heller | G06F 9/44526 715/229 |
| 2016/0004628 | A1 * | 1/2016 | Gugri | G06F 11/3688 717/124 |
| 2017/0339250 | A1 * | 11/2017 | Momchilov | H04L 67/34 |

* cited by examiner

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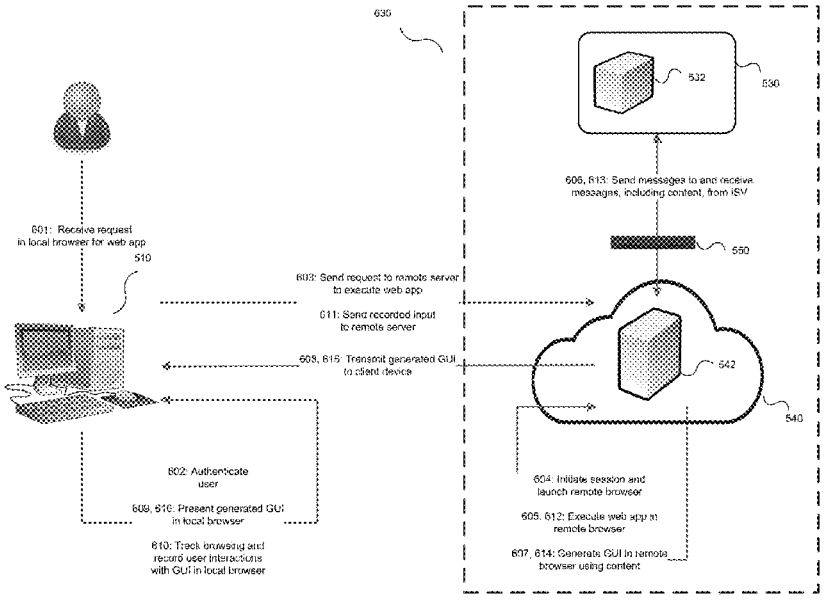
(57) **ABSTRACT**

Methods, devices, and computer-readable media for providing access to a web-based application from a remote computing device having a software environment that is incompatible with the web application are presented. In some embodiments, a virtual server may receive from a client device, a request to execute a web application, where at least a first portion of the web application may be hosted by the virtual server and a second portion of the web application may be hosted by a second server. In response to the request by the client device, the web application may be executed at the virtual server. Then a user interface of the web application may be sent to the client device to be presented in a local browser at the client device.

**20 Claims, 11 Drawing Sheets**



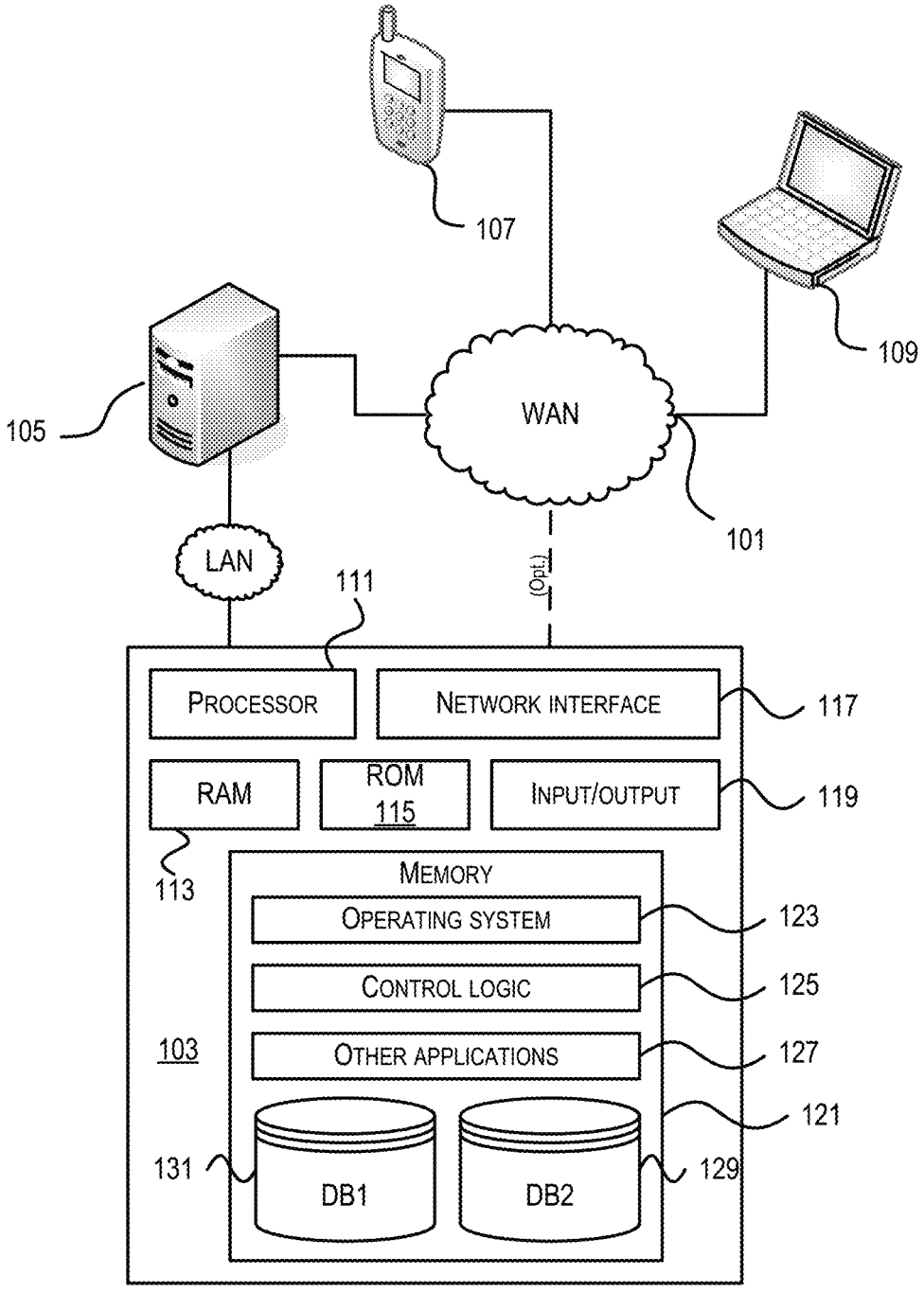

107
109
105
WAN
101
LAN
(Opt.)
111
PROCESSOR
NETWORK INTERFACE
117
RAM
ROM
115
INPUT/OUTPUT
119
113
MEMORY
OPERATING SYSTEM
123
CONTROL LOGIC
125
103
OTHER APPLICATIONS
127
121
131
DB1
DB2
129

FIG. 1

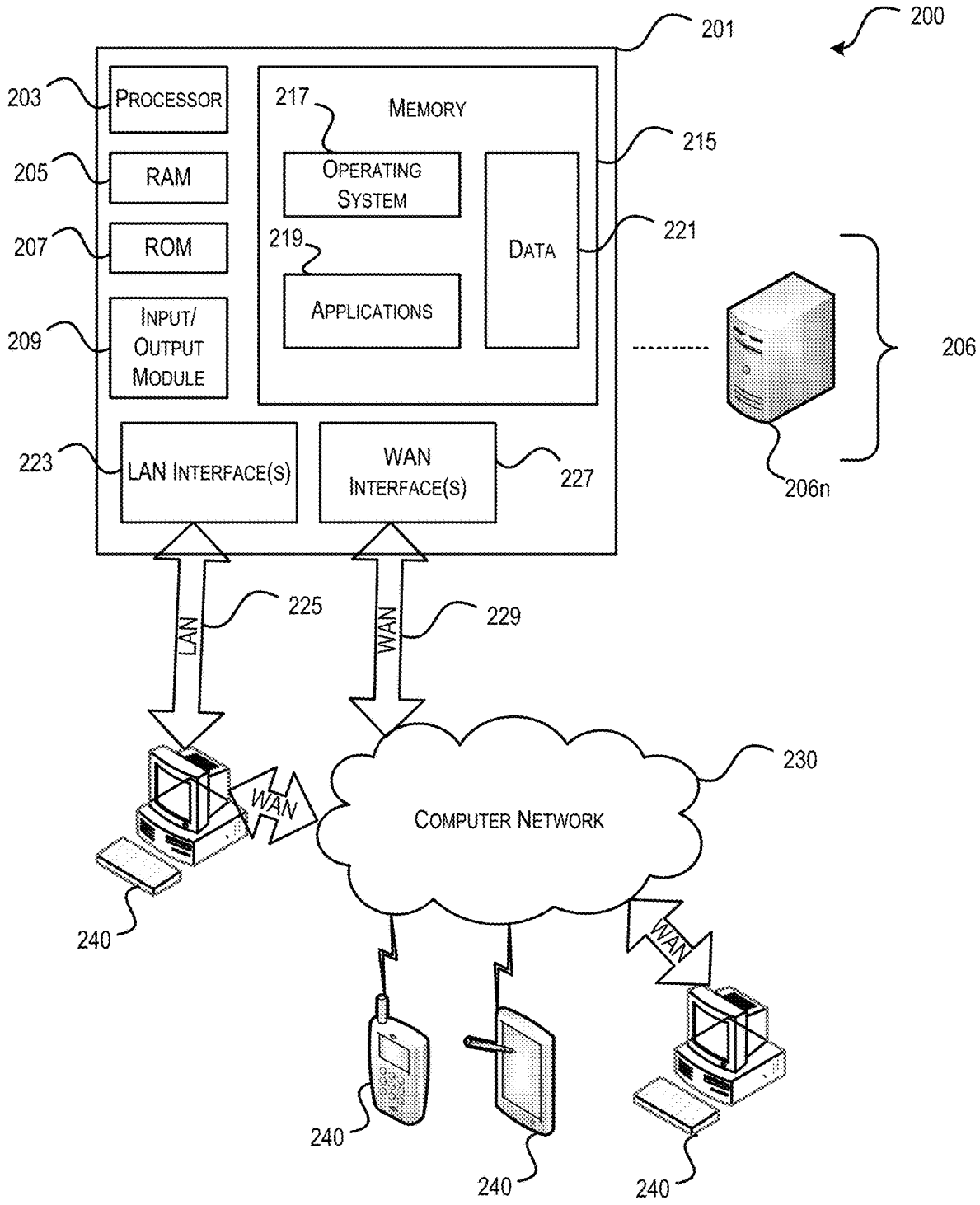

200
201
203
PROCESSOR
205
RAM
207
ROM
209
INPUT/ OUTPUT MODULE
217
MEMORY
OPERATING SYSTEM
219
APPLICATIONS
DATA
215
221
206
206n
223
LAN INTERFACE(S)
WAN INTERFACE(S)
227
LAN
225
WAN
229
230
COMPUTER NETWORK
WAN
240
240
240
240

FIG. 2

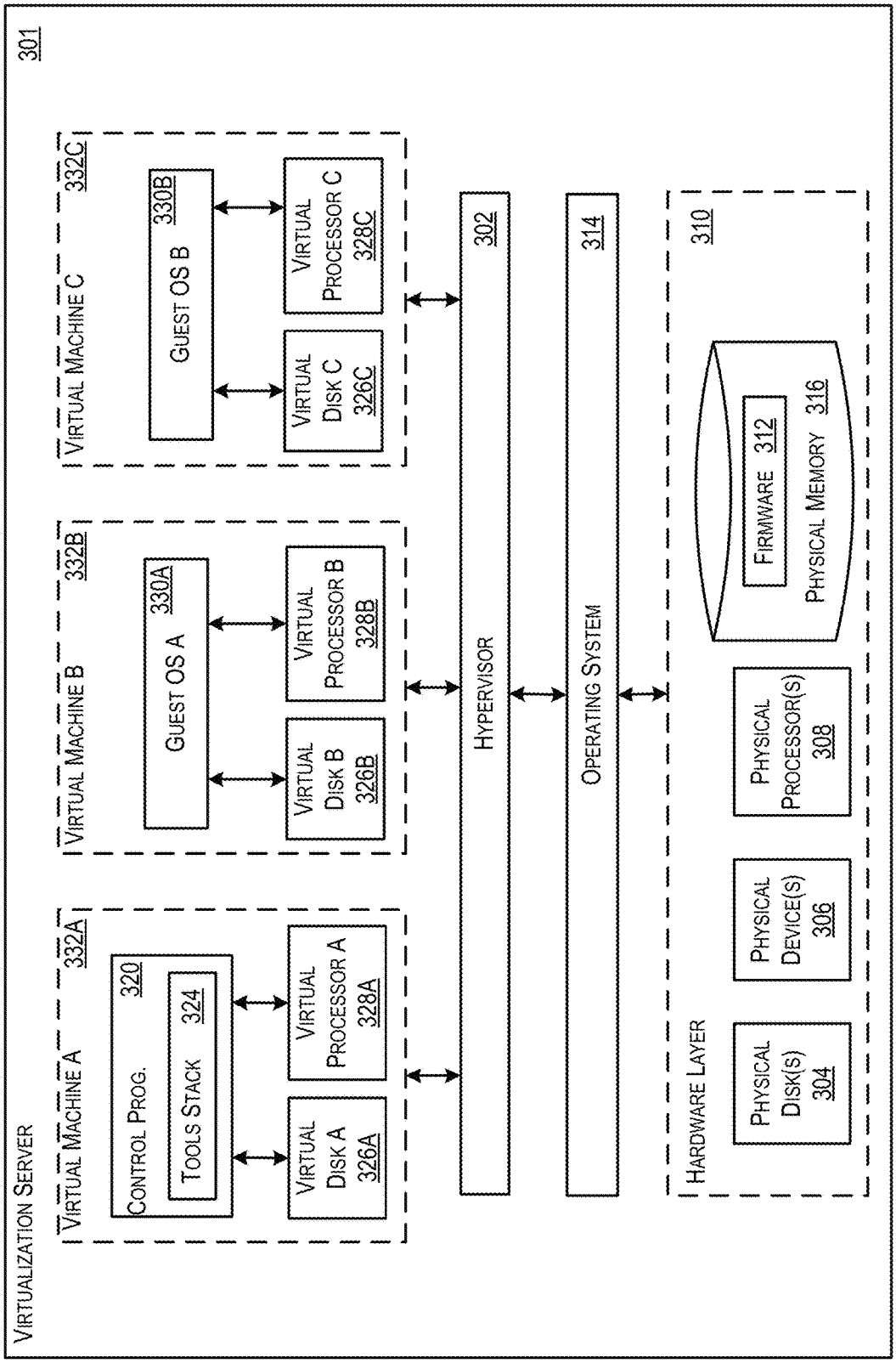

VIRTUALIZATION SERVER
301
VIRTUAL MACHINE A
332A
CONTROL PROG.
320
TOOLS STACK
324
VIRTUAL DISK A
326A
VIRTUAL PROCESSOR A
328A
VIRTUAL MACHINE B
332B
GUEST OS A
330A
VIRTUAL DISK B
326B
VIRTUAL PROCESSOR B
328B
VIRTUAL MACHINE C
332C
GUEST OS B
330B
VIRTUAL DISK C
326C
VIRTUAL PROCESSOR C
328C
HYPERVISOR
302
OPERATING SYSTEM
314
HARDWARE LAYER
310
PHYSICAL DISK(S)
304
PHYSICAL DEVICE(S)
306
PHYSICAL PROCESSOR(S)
308
FIRMWARE
312
PHYSICAL MEMORY
316

FIG. 3

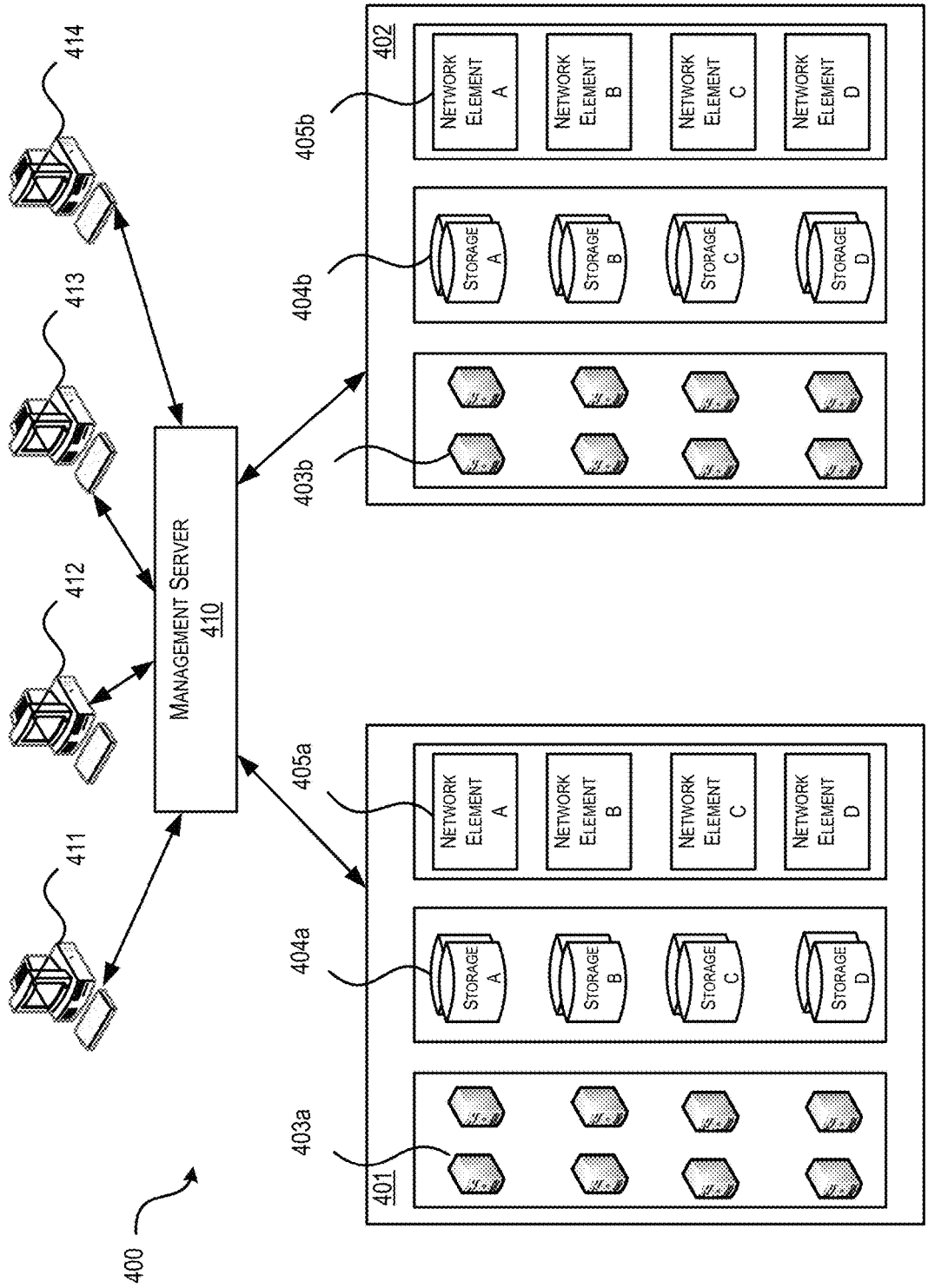

400
401
402
403a
403b
404a
404b
405a
405b
411
412
413
414
MANAGEMENT SERVER
410
NETWORK ELEMENT A
NETWORK ELEMENT B
NETWORK ELEMENT C
NETWORK ELEMENT D
STORAGE A
STORAGE B
STORAGE C
STORAGE D

FIG. 4

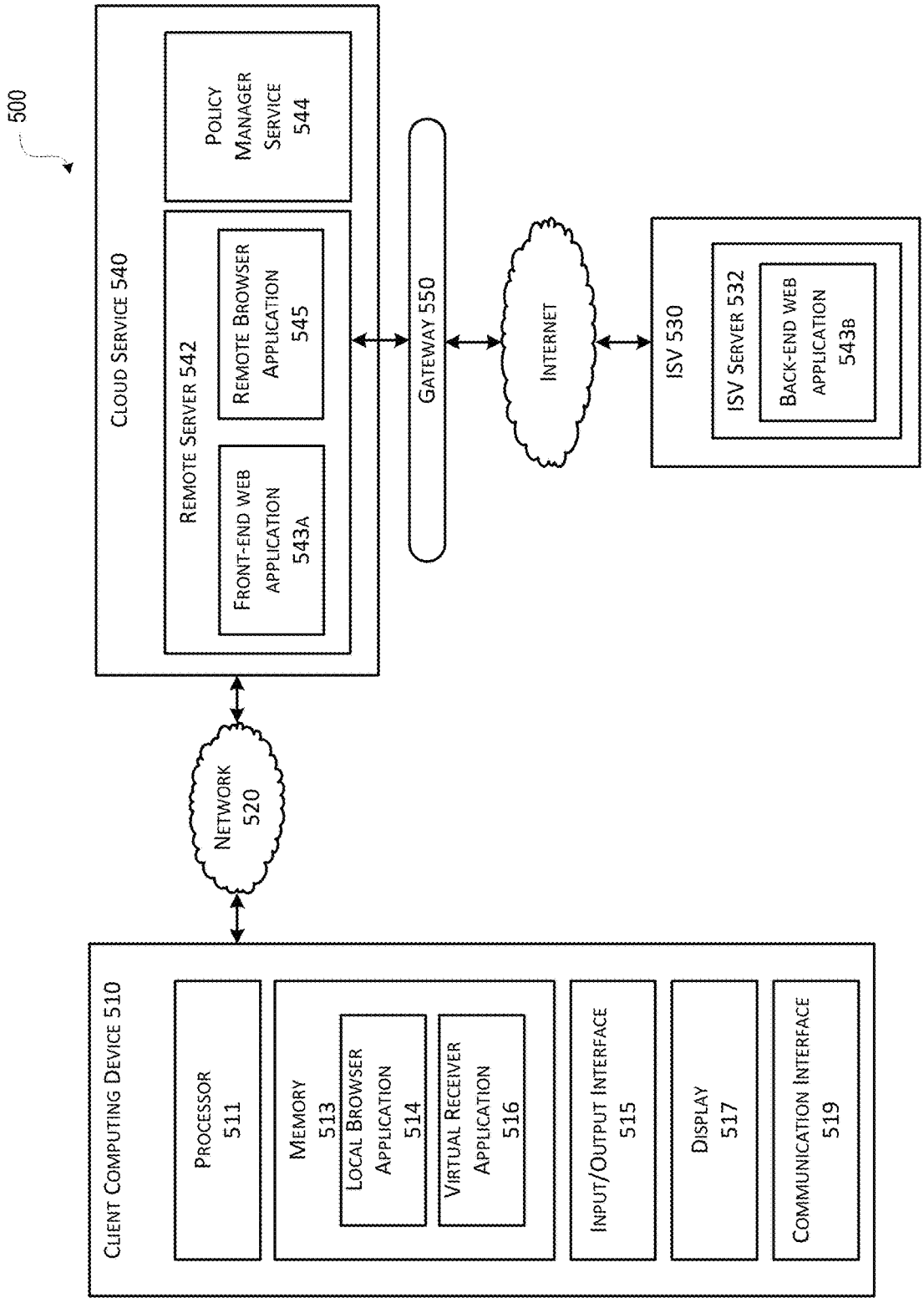

500
Cloud Service 540
Policy Manager Service 544
Remote Server 542
Remote Browser Application 545
Front-end web application 543A
Gateway 550
Internet
ISV 530
ISV Server 532
Back-end web application 543B
Network 520
Client Computing Device 510
Processor 511
Memory 513
Local Browser Application 514
Virtual Receiver Application 516
Input/Output Interface 515
Display 517
Communication Interface 519

FIG. 5

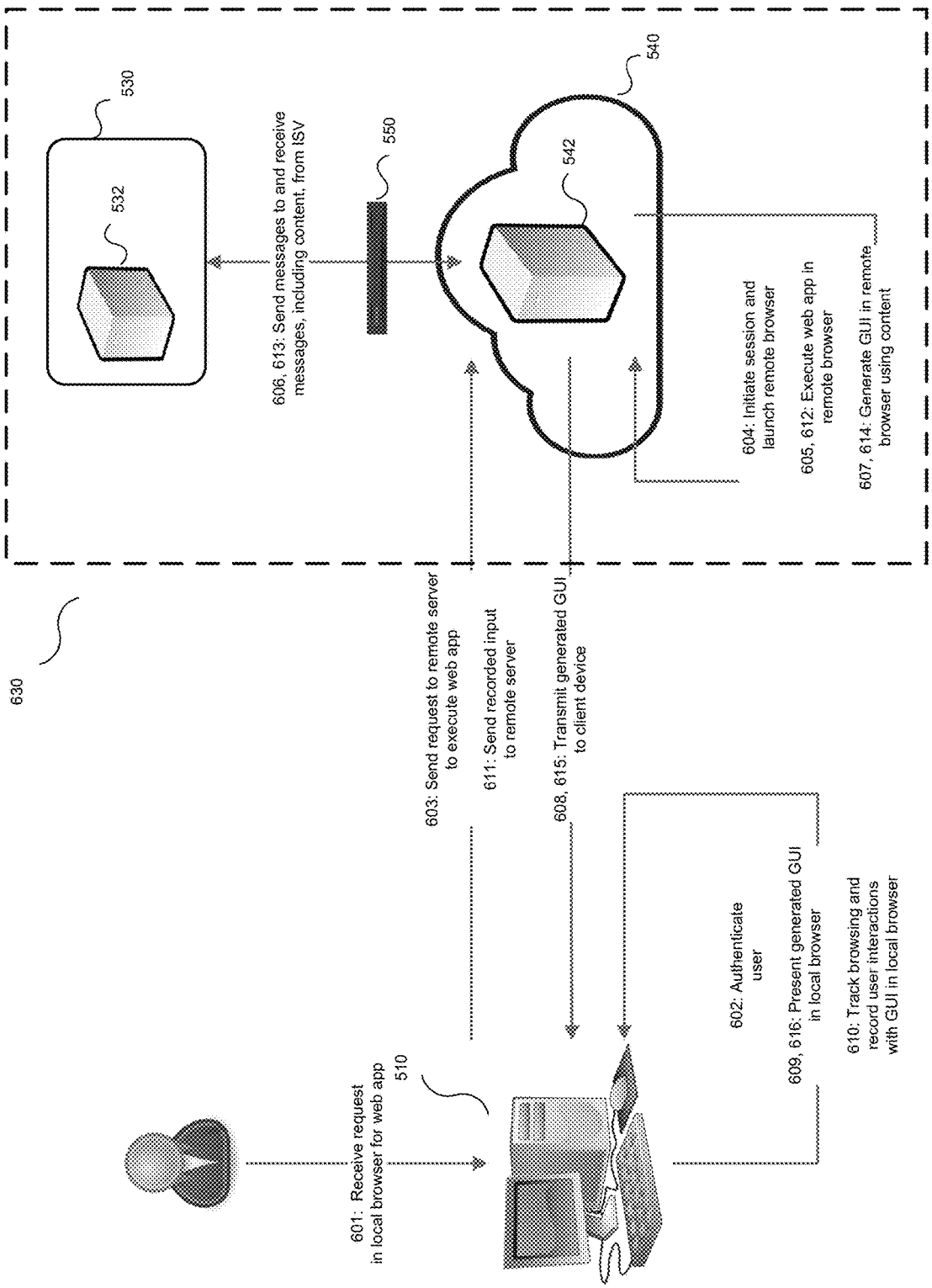

630
530
532
550
540
542
606, 613: Send messages to and receive messages, including content, from ISV
604: Initiate session and launch remote browser
605, 612: Execute web app in remote browser
607, 614: Generate GUI in remote browser using content
603: Send request to remote server to execute web app
611: Send recorded input to remote server
608, 615: Transmit generated GUI to client device
510
601: Receive request in local browser for web app
602: Authenticate user
609, 616: Present generated GUI in local browser
610: Track browsing and record user interactions with GUI in local browser

FIG. 6

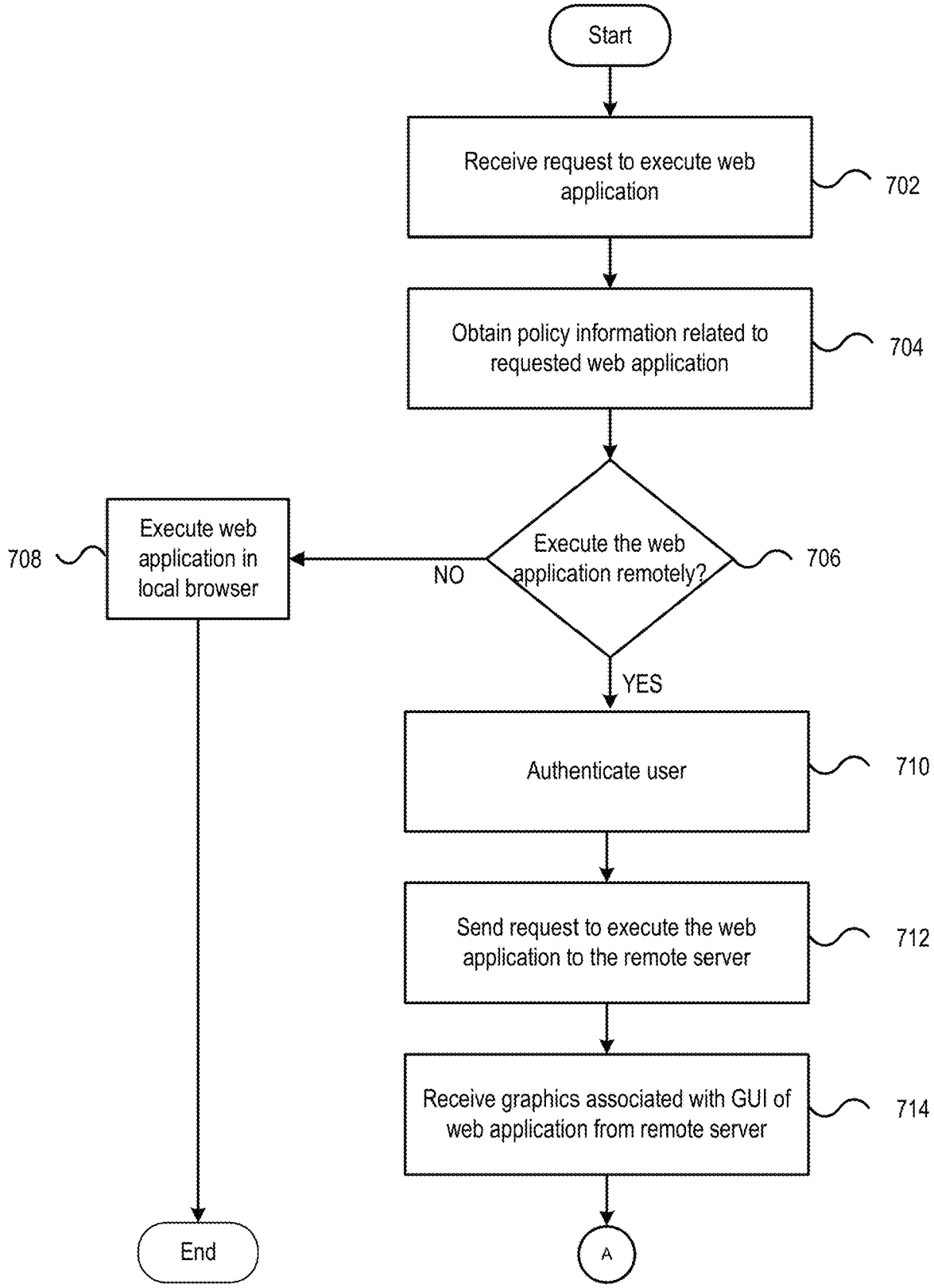

Start
Receive request to execute web application
702
Obtain policy information related to requested web application
704
Execute the web application remotely?
706
NO
Execute web application in local browser
708
YES
Authenticate user
710
Send request to execute the web application to the remote server
712
Receive graphics associated with GUI of web application from remote server
714
End
A

FIG. 7A

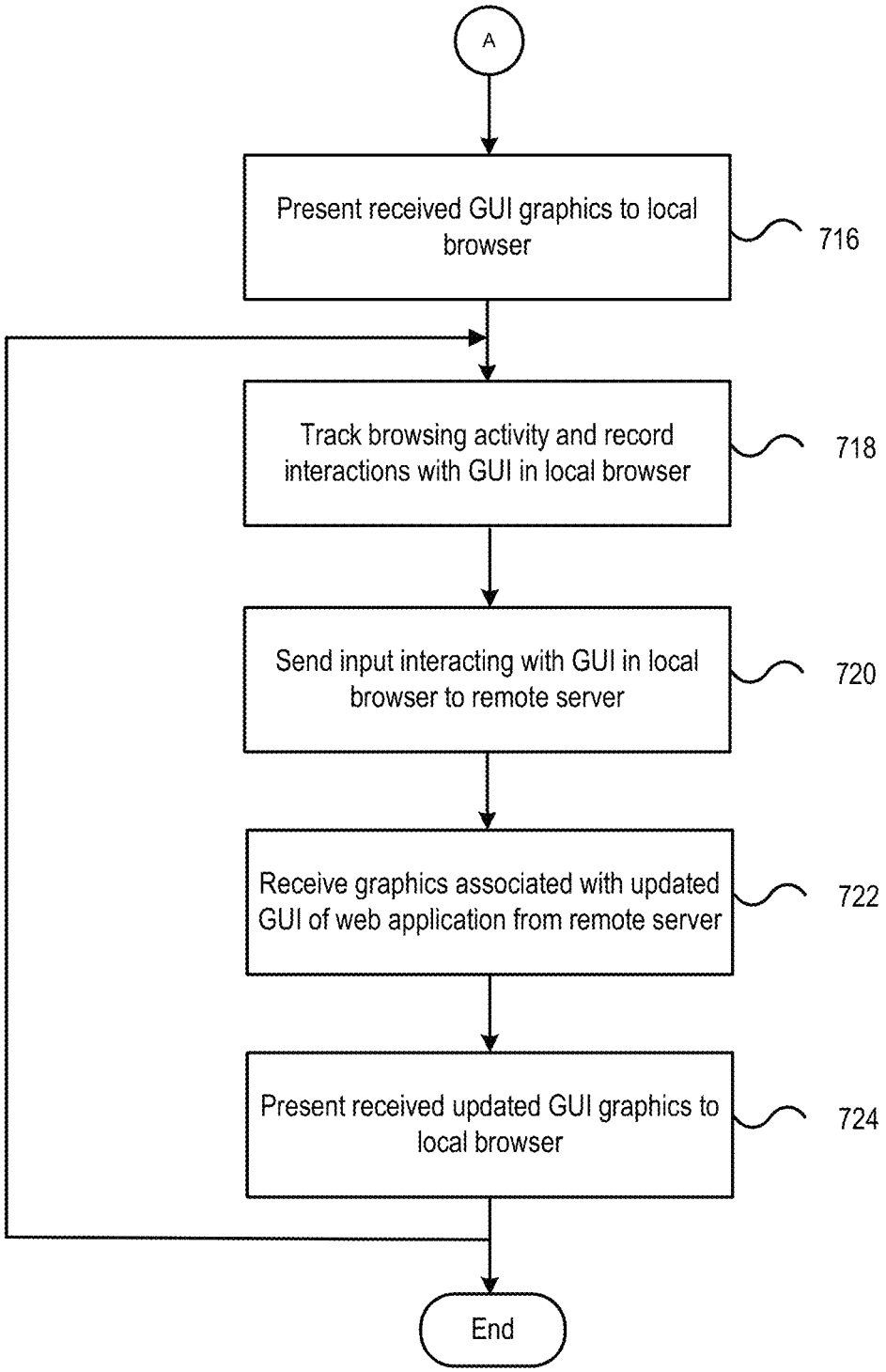

A
Present received GUI graphics to local browser
716
Track browsing activity and record interactions with GUI in local browser
718
Send input interacting with GUI in local browser to remote server
720
Receive graphics associated with updated GUI of web application from remote server
722
Present received updated GUI graphics to local browser
724
End

FIG. 7B

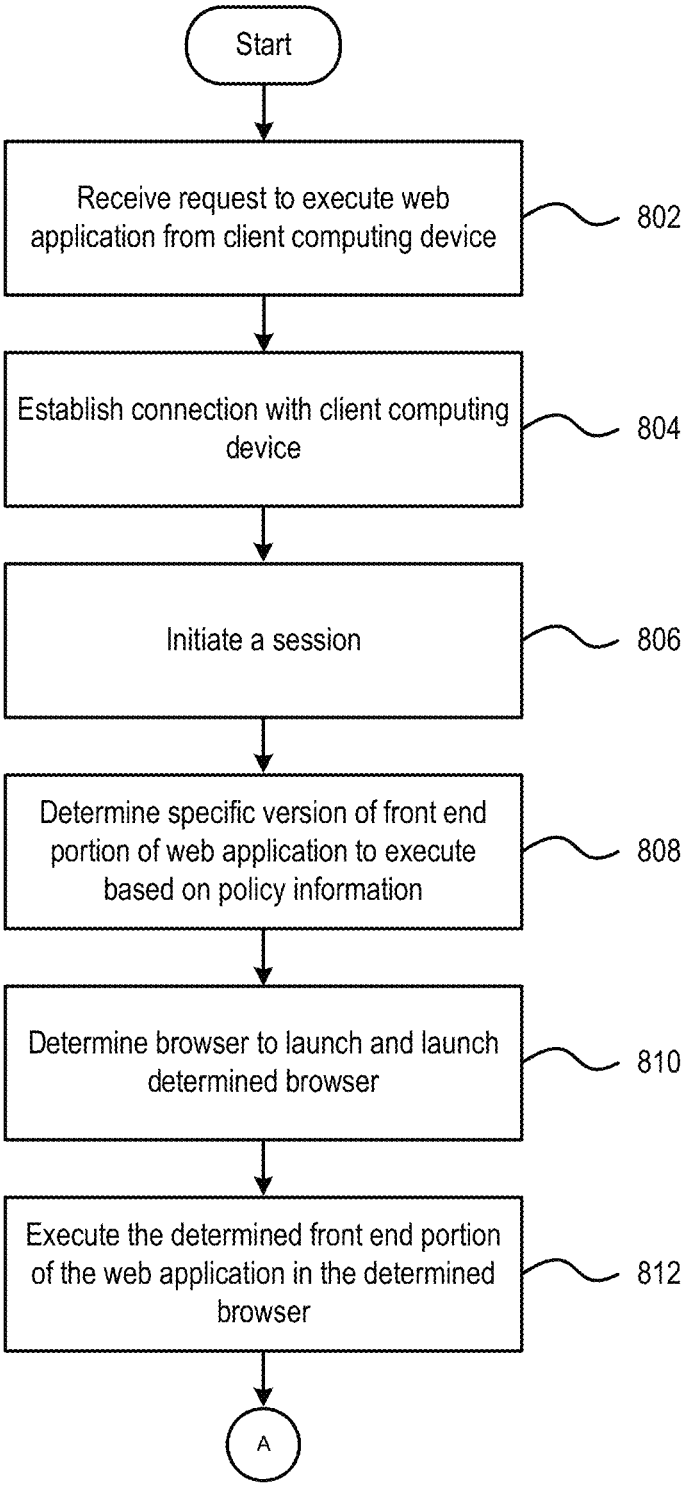

Start
Receive request to execute web application from client computing device
802
Establish connection with client computing device
804
Initiate a session
806
Determine specific version of front end portion of web application to execute based on policy information
808
Determine browser to launch and launch determined browser
810
Execute the determined front end portion of the web application in the determined browser
812
A

FIG. 8A

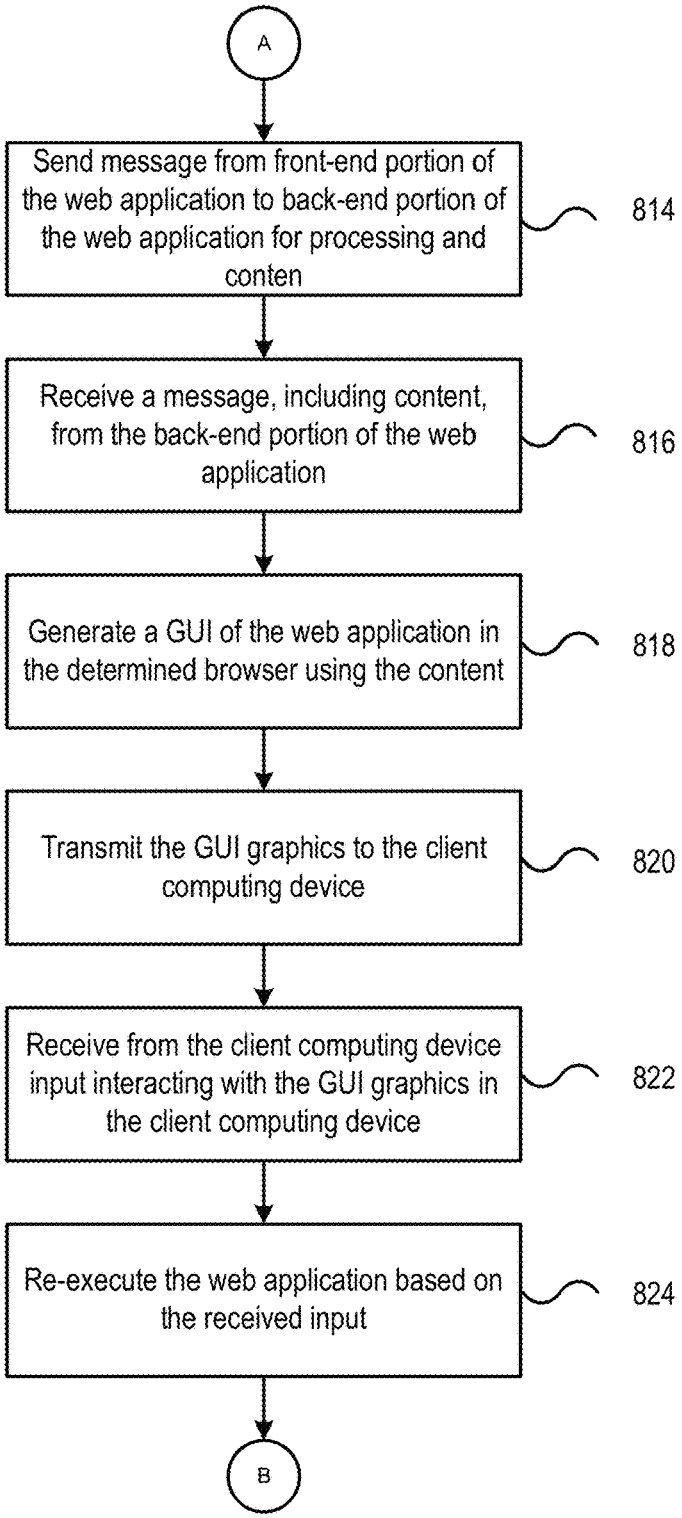

A
Send message from front-end portion of the web application to back-end portion of the web application for processing and conten
814
Receive a message, including content, from the back-end portion of the web application
816
Generate a GUI of the web application in the determined browser using the content
818
Transmit the GUI graphics to the client computing device
820
Receive from the client computing device input interacting with the GUI graphics in the client computing device
822
Re-execute the web application based on the received input
824
B

FIG. 8B

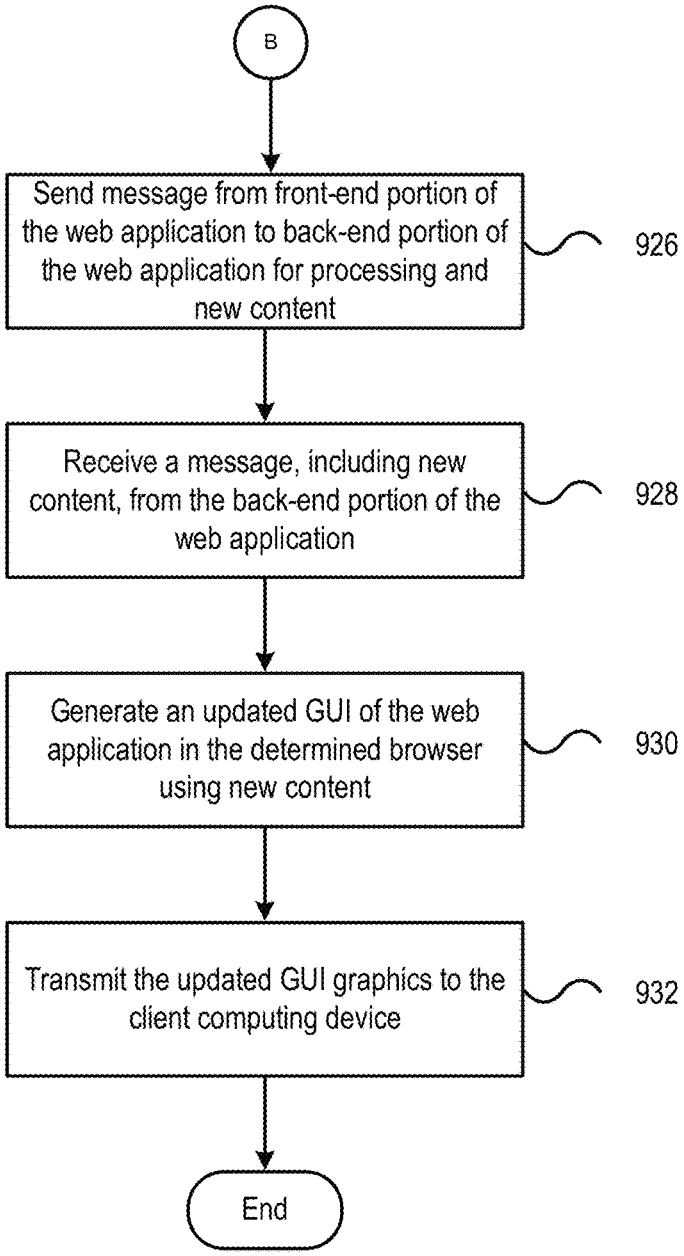

B
Send message from front-end portion of the web application to back-end portion of the web application for processing and new content
926
Receive a message, including new content, from the back-end portion of the web application
928
Generate an updated GUI of the web application in the determined browser using new content
930
Transmit the updated GUI graphics to the client computing device
932
End

FIG. 8C

# RENDERING A WEB APPLICATION IN A CLOUD SERVICE

## FIELD

Aspects of the disclosure relate generally to computer hardware and software. In particular, one or more aspects of the disclosure relate to computer hardware and software for hosting a web application in a cloud service.

## BACKGROUND

Users are increasingly using mobile and other remote computing devices to access software and services hosted remotely—such as those provided by a user's employer or those which the user has subscribed to from an independent software vendor (ISV). Such remote users require the ability to access these remote services to perform a variety of functions, such as sending and receiving email, managing calendars and tasks, creating and viewing content, executing applications, etc. As such remote access has become increasingly important for organizations and their users, organizations must find ways to support access to their systems and applications from a variety of disparate hardware and software environments. This presents a technical challenge when, for example, a remote user's software environment is incompatible with the organization's systems and/or applications.

## SUMMARY

Aspects of the disclosure provide technical solutions that may address and overcome one or more technical challenges associated with providing access to software and services, from remote computing environments.

In particular, one or more aspects of the disclosure describes providing access to a web-based application ("a web application") from a remote computing device having a software environment that is incompatible with the web application. For example, by implementing one or more aspects of the disclosure, a web application may be "hosted" in a cloud service environment and may be accessed by a remote user via a virtual browser also hosted in the cloud service environment. In this way, a remote user may seamlessly access, via a virtual environment, a web application that is incompatible with the remote user's native software environment.

In accordance with an aspect of the disclosure, a virtual server may receive from a client device, a request to execute a web application, where at least a first portion of the web application may be hosted by the virtual server and a second portion of the web application may be hosted by a second server. In response to the request by the client device, the web application may be executed at the virtual server. Then a user interface of the web application may be sent to the client device.

In accordance with another aspect of the disclosure, a server having a processor, a communication interface couple to the processer, and a memory storing a browser application and at least a first portion of a web application, may have the processor configured to receive, from a client device, via the communication interface, a request to execute the web application. In response to the request from the client device, the processor may be configured to execute the web application. Then the processor may be configured to send the user interface of the web application to the client device, via the communication interface. A second portion of the web application may be hosted by a second server.

In accordance with yet another aspect of the disclosure, instructions may be stored on a non-transitory, computer-readable storage medium, and the when the instructions are executed by a client device, the instructions configure the client device to output a client browser application for display in a display of the client device. The instructions may further configure the client device to receive a first request to execute a web application, via the client browser application. The instructions may further configure the client device to send, to a virtual server and in response to the first request, a second request to execute a virtualized web application corresponding to the requested web application. The instructions may further configure the client device to receive, from the virtual server and in response to the second request, a user interface of the virtualized web application. The instructions may further configure the client device to output the user interface of the virtualized web application, to the client browser application. At least a first portion of the virtualized web application may be hosted by the virtual server and a second portion of the virtualized web application may be hosted by a second server.

These features, along with many others, are discussed in greater detail below.



## BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of aspects described herein and the advantages thereof may be acquired by referring to the following description in consideration of the accompanying drawings, in which like reference numbers indicate like features and elements, and in which:

FIG. **1** depicts an illustrative computer system architecture that may be used in accordance with one or more illustrative aspects described herein;

FIG. **2** depicts an illustrative remote-access system architecture that may be used in accordance with one or more illustrative aspects described herein;

FIG. **3** depicts an illustrative virtualized (hypervisor) system architecture that may be used in accordance with one or more illustrative aspects described herein;

FIG. **4** depicts an illustrative cloud-based system architecture that may be used in accordance with one or more illustrative aspects described herein;

FIG. **5** depicts an illustrative computing environment for rendering a web-based application in a cloud service in accordance with one or more illustrative aspects described herein;

FIG. **6** depicts an illustrative event sequence for rendering a web-based application in a cloud service in accordance with one or more illustrative aspects described herein;

FIGS. **7**A-**7**B depict a flowchart of an illustrative method of a client computing device for rendering a web-based application in a cloud service in accordance with one or more illustrative aspects described herein; and

FIGS. **8**A-**8**C depict a flowchart of an illustrative method of a remote server for rendering a web-based application in a cloud service in accordance with one or more illustrative aspects described herein.

## DETAILED DESCRIPTION

In the following description, reference is made to the accompanying drawings identified above and which form a part hereof, and in which is shown, by way of illustration, various embodiments in which aspects described herein may

be practiced. It is to be understood that other embodiments may be utilized and structural and functional modifications may be made without departing from the scope described herein. Various aspects are capable of other embodiments and of being practiced or being carried out in various different ways.

It is to be understood that the phraseology and terminology used herein are for the purpose of description and should not be regarded as limiting. Rather, the phrases and terms used herein are to be given their broadest interpretation and meaning. The use of "including" and "comprising", and variations thereof, is meant to encompass the items listed thereafter and equivalents thereof, as well as additional items and equivalents thereof. The use of the terms "mounted," "connected," "coupled," "positioned," "engaged" and similar terms, is meant to include both direct and indirect mounting, connecting, coupling, positioning and engaging.

Computing Architecture.

Computer software, hardware, and networks, described herein, may be utilized in a variety of different system environments, including standalone, networked, remote-access (aka, remote desktop), virtualized, and/or cloud-based environments, among others.

FIG. **1** depicts an illustrative computer system architecture that may be used in accordance with one or more illustrative aspects described herein.

Referring to FIG. **1**, an example of a system architecture and various data processing devices that may be used to implement one or more illustrative aspects described herein in a standalone and/or networked environment is provided. Those of skill in the art will appreciate that the specific network architecture and data processing devices used may vary and are secondary to the functionality that they provide, as further described herein.

Various components and devices of the system, such as data server **103**, web server **105**, and client computers **107** and **109**, may be interconnected via a network **101**, such as a wide area network (WAN), e.g., the Internet. Other networks may also, or alternatively, be used, including private intranets, corporate networks, local area networks (LAN), metropolitan area networks (MAN), wireless networks, personal networks (PAN), and the like. Network **101** is for illustration purposes and may be replaced with fewer or additional computer networks. A local area network may have one or more of any known LAN topology and may use one or more of a variety of different protocols, such as Ethernet. The devices **103**, **105**, **107**, **109** and other devices (not shown) may be connected to one or more of the networks **101** via twisted pair wires, coaxial cable, fiber optics, radio waves, or other communication media. The term "network", as used herein and as depicted in the drawings, refers not only to systems in which remote storage devices are coupled together via one or more communication paths, but also to stand-alone devices that may be coupled, from time to time, to such systems that have storage capability. Consequently, the term "network" includes not only a "physical network", but also a "content network," which is comprised of the data—attributable to a single entity—which resides across all physical networks.

Data server **103** provides overall access, control and administration of databases and control software for performing one or more illustrative aspects described herein. The data server **103** may be connected to web server **105**, through which users interact with and obtain data as requested. Alternatively, data server **103** may act as a web server itself and be directly connected to the Internet. Data server **103** may be connected to web server **105** through the network **101** (e.g., the Internet), via direct or indirect connection, or via some other network. Users may interact with the data server **103** using client computers **107**, **109**, e.g., using the web browser **105** to connect to the data server **103** via one or more externally exposed web sites hosted by web server **105**.

Client computers **107**, **109** may be used in concert with data server **103** to access data stored therein, or may be used for other purposes. For example, from client computer **107**, a user may access web server **105** using an Internet browser, as is known in the art, or by executing a software application that communicates with web server **105** and/or data server **103** over the network **101** (such as the Internet).

Servers and applications may be combined on the same physical machines, and retain separate virtual or logical addresses, or may reside on separate physical machines. For example, services provided by web server **105** and data server **103** may be combined on a single server. Each device **103**, **105**, **107**, **109** may be any type of known computer, server, or data processing device.

Data server **103**, for example, may include a processor **111**, random access memory (RAM) **113**, read only memory (ROM) **115**, network interface **117**, input/output (I/O) interface **119** (e.g., keyboard, mouse, display, printer, etc.), and memory **121**.

Processor **111** may control overall operation of the data server **103**.

I/O interface **119** may include a variety of interface units and drives for reading, writing, displaying, and/or printing data or files.

Memory **121** may store operating system software **123** for controlling overall operation of data server **103**, control logic **125** for instructing data server **103** to perform aspects described herein, and other application software **127** providing secondary support and/or other functionality, which may or may not be used in conjunction with aspects described herein. The control logic **125** may also be referred to herein as the data server software **125**. Functionality of the data server software **125** may refer to operations or decisions made automatically based on rules coded into the control logic, made manually by a user providing input into the system, and/or a combination of automatic processing based on user input (e.g., queries, data updates, etc.). Memory **121** may also store data used in the performance of one or more aspects described herein, including a first database **131** and a second database **129**. In some embodiments, the first database **131** may include the second database **129** (e.g., as a separate table, report, etc.). That is, the information can be stored in a single database, or separated into different logical, virtual, or physical databases, depending on system design.

Devices **105**, **107**, **109** may have similar or different architecture as described with respect to data server **103**. Those of skill in the art will appreciate that the functionality of data server **103** (or devices **105**, **107**, **109**) as described herein may be spread across multiple data processing devices, for example, to distribute processing load across multiple computers, to segregate transactions based on geographic location, user access level, quality of service (QoS), etc.

One or more aspects of the disclosure may be embodied in computer-usable or readable data and/or computer-executable instructions, such as in one or more program modules, executed by one or more computers or other devices as described herein. Generally, program modules include routines, programs, objects, components, data struc-

tures, etc. that perform particular tasks or implement particular abstract data types when executed by a processor in a computer or other device. The modules may be written in a source code programming language that is subsequently compiled for execution, or may be written in a scripting language, such as (but not limited to) HyperText Markup Language (HTML) or Extensible Markup Language (XML). The computer executable instructions may be stored on a computer-readable medium, such as a nonvolatile storage device. Any suitable computer-readable storage media may be utilized, including hard disks, CD-ROMs, optical storage devices, magnetic storage devices, and/or any combination thereof. In addition, various transmission (non-storage) media representing data or events, as described herein, may be transferred between a source and a destination in the form of electromagnetic waves traveling through signal-conducting media, such as metal wires, optical fibers, and/or wireless transmission media (e.g., air and/or space). Various aspects described herein may be embodied as a method, a data processing system, or a computer program product. Therefore, various functionalities may be embodied in whole or in part in software, firmware and/or hardware or hardware equivalents, such as integrated circuits, field programmable gate arrays (FPGA), and the like. Particular data structures may be used to more effectively implement one or more aspects described herein, and such data structures are contemplated within the scope of computer executable instructions and computer-usable data described herein.

FIG. **2** depicts an illustrative remote-access system architecture that may be used in accordance with one or more illustrative aspects described herein.

Referring to FIG. **2**, an example of a system architecture, including a computing device **201** in an illustrative computing environment **200**, that may be used to implement one or more illustrative aspects described herein is provided. Those of skill in the art will appreciate that the specific network architecture and data processing devices used may vary and are secondary to the functionality that they provide, as further described herein.

Computing device **201** may be used as a server **206***a* in a single-server or multi-server desktop virtualization system (e.g., a remote access or cloud system) configured to provide virtual machines for client access devices. The computing device **201** may have a processor **203**, RAM **205**, ROM **207**, I/O module **209**, memory **215**, LAN interface **223**, and WAN interface **227**.

The processor **203** may control overall operation of the computing device **201** and its associated components.

I/O module **209** may include a mouse, keypad, touch screen, scanner, optical reader, and/or stylus (or other input devices), through which a user of computing device **201** may provide input, and may also include one or more of a speaker for providing audio output and a video display device for providing textual, audiovisual, and/or graphical output.

Memory **215** and/or other storage may store software to provide instructions to processor **203** for configuring computing device **201** into a special purpose computing device in order to perform various functions as described herein. For example, memory **215** may store software used by the computing device **201**, such as an operating system **217**, application programs **219**, and an associated database **221**.

Computing device **201** may operate in a networked environment supporting connections to one or more remote computers, such as terminals **240** (also referred to as client devices). The terminals **240** may be personal computers (PCs), mobile devices, laptop computers, tablets, or servers that include many or all of the elements described above with respect to the data server **103** or the computing device **201**. The network connections depicted in FIG. **2** include a LAN **225** and a WAN **229**, but may also include other networks. When used in a LAN networking environment, computing device **201** may be connected to the LAN **225** through the LAN interface or adapter **223**. When used in a WAN networking environment, computing device **201** may include the WAN interface **227**, e.g., a modem, for establishing communications over the WAN **229**, such as with a computer network **230** (e.g., the Internet). It will be appreciated that the network connections shown are illustrative and other means of establishing a communications link between the computers may be used. Computing device **201** and/or terminals **240** may also be mobile terminals (e.g., mobile phones, smartphones, personal digital assistants (PDAs), notebooks, etc.) including various other components, such as a battery, speaker, and antennas (not shown).

Aspects described herein may also be operational with numerous other general purpose or special purpose computing system environments or configurations. Examples of other computing systems, environments, and/or configurations that may be suitable for use with aspects described herein include, but are not limited to, PCs, server computers, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set-top boxes, programmable consumer electronics, network PCs, minicomputers, mainframe computers, distributed computing environments that include any of the above systems or devices, and the like.

As shown in FIG. **2**, one or more client devices **240** may be in communication with one or more servers **206***a*-**206***n* (generally referred to herein as "server(s) **206**"). In one embodiment, the computing environment **200** may include a network appliance installed between the servers **206** and client devices **240**. The network appliance may manage client/server connections, and in some cases can load balance client connections amongst a plurality of backend servers **206**.

The client devices **240** may, in some embodiments, be referred to as a single client device **240** or a single group of client devices **240**, while servers **206** may be referred to as a single server **206** or a single group of servers **206**. In one embodiment, a single client device **240** communicates with more than one server **206**, while in another embodiment, a single server **206** communicates with more than one client device **240**. In yet another embodiment, a single client device **240** communicates with a single server **206**.

A client device **240** can, in some embodiments, be referenced by any one of the following non-exhaustive terms: client machine(s); client(s); client computer(s); client device (s); client computing device(s); local machine; remote machine; client node(s); endpoint(s); or endpoint node(s). The server **206**, in some embodiments, may be referenced by any one of the following non-exhaustive terms: server(s), local machine; remote machine; server farm(s), or host computing device(s).

In one embodiment, the client device **240** may be a virtual machine. The virtual machine may be any virtual machine, while in some embodiments the virtual machine may be any virtual machine managed by a Type 1 or Type 2 hypervisor, for example, a hypervisor developed by Citrix Systems, IBM, VMware, or any other hypervisor. In some aspects, the virtual machine may be managed by a hypervisor, while in other aspects, the virtual machine may be managed by a hypervisor executing on a server **206** or a hypervisor executing on a client device **240**.

Some embodiments include a client device **240** that displays application output generated by an application

remotely executing on a server **206** or other remotely located machine. In these embodiments, the client device **240** may execute a virtual machine receiver program or application to display the output in an application window, a browser, or other output window. In one example, the application is a desktop, while in other examples the application is an application that generates or presents a desktop. A desktop may include a graphical shell providing a user interface for an instance of an operating system in which local and/or remote applications can be integrated. Applications, as used herein, are programs that execute after an instance of an operating system (and, optionally, also the desktop) has been loaded.

The server **206**, in some embodiments, uses a remote presentation protocol or other program to send data to a thin-client or remote-display application executing on the client to present display output generated by an application executing on the server **206**. The thin-client or remote-display protocol can be any one of the following non-exhaustive list of protocols: the Independent Computing Architecture (ICA) protocol developed by Citrix Systems, Inc. of Ft. Lauderdale, Fla.; or the Remote Desktop Protocol (RDP) manufactured by the Microsoft Corporation of Redmond, Wash.

The remote computing environment **200** may include more than one server **206***a*-**206***n* such that the servers **206***a*-**206***n* are logically grouped together into a server farm **206**, for example, in a cloud computing environment. The server farm **206** may include servers **206***a*-**206***n* that are geographically dispersed while logically grouped together, or servers **206***a*-**206***n* that are located proximate to each other while logically grouped together. Geographically dispersed servers **206***a*-**206***n* within a server farm **206** can, in some embodiments, communicate using a WAN, MAN, or LAN, where different geographic regions can be characterized as: different continents; different regions of a continent; different countries; different states; different cities; different campuses; different rooms; or any combination of the preceding geographical locations. In some embodiments the server farm **206** may be administered as a single entity, while in other embodiments, the server farm **206** can include multiple server farms.

In some embodiments, a server farm **206** may include servers **206***a*-**206***n* that execute a substantially similar type of operating system platform (e.g., WINDOWS, UNIX, LINUX, iOS, ANDROID, SYMBIAN, etc.). In other embodiments, server farm **206** may include a first group of one or more servers that execute a first type of operating system platform, and a second group of one or more servers that execute a second type of operating system platform.

Server **206** may be configured as any type of server, as needed, e.g., a file server, an application server, a web server, a proxy server, an appliance, a network appliance, a gateway, an application gateway, a gateway server, a virtualization server, a deployment server, a Secure Sockets Layer (SSL) Virtual Private Network (VPN) server, a firewall, a web server, an application server or master application server, a server executing an active directory, or a server executing an application acceleration program that provides firewall functionality, application functionality, or load balancing functionality. Other server types may also be used.

Some embodiments include a first server **206***a* that receives requests from a client device **240**, forwards the request to a second server **206***b*, and responds to the request generated by the client device **240** with a response from the second server **206***b*. First server **206***a* may acquire an enumeration of applications available to the client device **240** as well as address information associated with an application server **206** hosting an application identified within the enumeration of applications. First server **206***a* can then present a response to the client's request using a web interface, and communicate directly with the client device **240** to provide the client device **240** with access to an identified application. One or more client devices **240** and/or one or more servers **206** may transmit data over computer network **230**, e.g., network **101**.

FIG. **3** depicts an illustrative virtualized (hypervisor) system architecture that may be used in accordance with one or more illustrative aspects described herein.

Referring to FIG. **3**, an example of a high-level architecture of an illustrative desktop virtualization system, including at least one virtualization server **301**, that may be used to implement one or more illustrative aspects described herein is provided. Those of skill in the art will appreciate that the specific network architecture and data processing devices used may vary and are secondary to the functionality that they provide, as further described herein.

As shown, the desktop virtualization system may be a single-server or multi-server system, or a cloud system, including the at least one virtualization server **301**, which may be configured to provide virtual desktops and/or virtual applications to one or more client devices **240**. As used herein, a desktop refers to a graphical environment or space in which one or more applications may be hosted and/or executed. A desktop may include a graphical shell providing a user interface, for an instance, of an operating system in which local and/or remote applications can be integrated. Applications may include programs that execute after an instance of an operating system (and, optionally, also the desktop) has been loaded. Each instance of the operating system may be physical (e.g., one operating system per device) or virtual (e.g., many instances of an OS running on a single device). Each application may be executed on a local device, or executed on a remotely located device (e.g., remoted).

Virtualization server **301** may be configured as a virtualization server in a virtualization environment, for example, a single-server, multi-server, or cloud computing environment. Virtualization server **301** illustrated in FIG. **3** can be deployed as and/or implemented by one or more embodiments of the server **206** illustrated in FIG. **2** or by other known computing devices.

Virtualization server **301** may include a hardware layer **310** with one or more pieces of hardware that communicate with the virtualization server **301**. In some embodiments, the hardware layer **310** can include one or more physical disks **304**, one or more physical devices **306**, one or more physical processors **308**, and one or more physical memories **316**. Physical components **304**, **306**, **308**, and **316** may include, for example, any of the components described above.

Physical devices **306** may include, for example, a network interface card, a video card, a keyboard, a mouse, an input device, a monitor, a display device, speakers, an optical drive, a storage device, a universal serial bus connection, a printer, a scanner, a network element (e.g., router, firewall, network address translator, load balancer, VPN gateway, Dynamic Host Configuration Protocol (DHCP) router, etc.), or any device connected to or communicating with virtualization server **301**.

Physical processors **308** may execute programs or executable instructions stored in the physical memory **316**. Executing on one or more of the physical processors **308** may be one or more virtual machines **332**A-**332**C (generally virtual machine **332**). Each virtual machine **332** may have a virtual

disk **326**A-**326**C and a virtual processor **328**A-**328**C. In some embodiments, a first virtual machine **332**A may execute, using a virtual processor **328**A, a control program **320** that includes a tools stack **324**. Control program **320** may be referred to as a control virtual machine, Dom0, Domain 0, or other virtual machine used for system administration and/or control. In some embodiments, one or more virtual machines **332**B-**332**C can execute, using a virtual processor **328**B-**328**C, a guest operating system **330**A-**330**B.

Physical memory **316** may include any type of memory. Physical memory **316** may store data, and in some embodiments may store one or more programs, or set of executable instructions. In some embodiments, firmware **312** can be stored within a memory element of the physical memory **316**.

Virtualization server **301** may further include an operating system **314** that may be stored in a memory element in the physical memory **316** and executed by one or more of the physical processors **308**.

Virtualization server **301** may further include a hypervisor **302** that may be stored in a memory element in the physical memory **316** and executed by one or more of the physical processors **308**. In some embodiments, hypervisor **302** may be a program executed by the physical processors **308** to create and manage any number of virtual machines **332**, such as virtual machines **332**A-**332**C. Hypervisor **302** may be referred to as a virtual machine monitor, or platform virtualization software. In some embodiments, hypervisor **302** can be any combination of executable instructions and hardware that monitors virtual machines executing on a computing machine. Hypervisor **302** may be Type 2 hypervisor, where the hypervisor executes within the operating system **314** executing on the virtualization server **301**. Virtual machines then execute at a level above the hypervisor **302**. In some embodiments, the Type 2 hypervisor executes within the context of a user's operating system, such that the Type 2 hypervisor interacts with the user's operating system. In other embodiments, one or more virtualization servers **301** in a virtualization environment may instead include a Type 1 hypervisor (not shown). A Type 1 hypervisor may execute on the virtualization server **301** by directly accessing the hardware and resources within the hardware layer **310**. That is, while a Type 2 hypervisor **302** accesses system resources through a host operating system **314**, as shown in FIG. **3**, a Type 1 hypervisor may directly access all system resources without the host operating system **314**. A Type 1 hypervisor may execute directly on one or more physical processors **308** of virtualization server **301**, and may include program data stored in the physical memory **316**.

Hypervisor **302** may be used to emulate virtual hardware, partition physical hardware, virtualize physical hardware, and/or execute virtual machines **332** that provide access to computing environments. In still other embodiments, hypervisor **302** controls processor scheduling and memory partitioning for virtual machines **332** executing on virtualization server **301**. Hypervisor **302** may include those manufactured by VMWare, Inc., of Palo Alto, Calif.; the XENPROJECT hypervisor, an open source product whose development is overseen by the open source XenProject.org community; HyperV, VirtualServer or virtual PC hypervisors provided by Microsoft, or others. In some embodiments, virtualization server **301** executes a hypervisor **302** that creates a virtual machine platform on which guest operating systems **330** may execute. In these embodiments, the virtualization server **301** may be referred to as a host server. An example of such a virtualization server is the XENSERVER provided by Citrix Systems, Inc., of Fort Lauderdale, Fla.

Hypervisor **302**, in some embodiments, can provide virtual resources to operating systems **330** or control programs **320** executing on virtual machines **332** in any manner that simulates the operating systems **330** or control programs **320** having direct access to system resources. System resources can include, but are not limited to, physical disks **304**, physical devices **306**, physical processors **308**, physical memory **316**, and any other component included in virtualization server **301** hardware layer **310**.

Hypervisor **302** may create the one or more virtual machines **332**B-**332**C in which guest operating systems **330** execute. In some embodiments, hypervisor **302** may load a virtual machine image to create a virtual machine **332**. In other embodiments, the hypervisor **302** may execute a guest operating system **330** within virtual machine **332**. In still other embodiments, virtual machine **332** may execute guest operating system **330**.

In addition to creating the virtual machines **332**, hypervisor **302** may control the execution of at least one virtual machine **332**. In other embodiments, hypervisor **302** may present at least one virtual machine **332** with an abstraction of at least one hardware resource provided by the virtualization server **301** (e.g., any hardware resource available within the hardware layer **310**). In other embodiments, hypervisor **302** may control the manner in which virtual machines **332** access physical processors **308** available in virtualization server **301**. Controlling access to physical processors **308** may include determining whether a virtual machine **332** should have access to a processor **308**, and how physical processor capabilities are presented to the virtual machine **332**.

As shown in FIG. **3**, virtualization server **301** may host or execute the one or more virtual machines **332**. A virtual machine **332** is a set of executable instructions that, when executed by a processor **308**, imitate the operation of a physical computer such that the virtual machine **332** can execute programs and processes much like a physical computing device. While FIG. **3** illustrates an embodiment where a virtualization server **301** hosts three virtual machines **332**, in other embodiments, virtualization server **301** can host any number of virtual machines **332**. Hypervisor **302**, in some embodiments, provides each virtual machine **332** with a unique virtual view of the physical hardware, memory, processor and other system resources available to that virtual machine **332**. In some embodiments, the unique virtual view can be based on one or more of virtual machine permissions, application of a policy engine to one or more virtual machine identifiers, a user accessing a virtual machine, the applications executing on a virtual machine, networks accessed by a virtual machine, or any other desired criteria. For instance, hypervisor **302** may create one or more unsecure virtual machines **332** and one or more secure virtual machines **332**. Unsecure virtual machines **332** may be prevented from accessing resources, hardware, memory locations, and programs that secure virtual machines **332** may be permitted to access. In other embodiments, hypervisor **302** may provide each virtual machine **332** with a substantially similar virtual view of the physical hardware, memory, processor and other system resources available to the virtual machines **332**.

Each virtual machine **332** may include the virtual disks **326**A-**326**C (generally virtual disk **326**) and the virtual processors **328**A-**328**C (generally virtual processor **328**.) The virtual disk **326**, in some embodiments, is a virtualized view of one or more physical disks **304** of the virtualization

server **301**, or a portion of one or more physical disks **304** of the virtualization server **301**. The virtualized view of the physical disks **304** can be generated, provided and managed by the hypervisor **302**. In some embodiments, the hypervisor **302** provides each virtual machine **332** with a unique view of the physical disks **304**. Thus, in these embodiments, the particular virtual disk **326** included in each virtual machine **332** can be unique when compared with the other virtual disks **326**.

The virtual processor **328** can be a virtualized view of the one or more physical processors **308** of the virtualization server **301**. In some embodiments, the virtualized view of the physical processors **308** can be generated, provided, and managed by the hypervisor **302**. In some embodiments, the virtual processor **328** has substantially all of the same characteristics of at least one physical processor **308**. In other embodiments, the virtual processor **308** provides a modified view of the physical processors **308** such that at least some of the characteristics of the virtual processor **328** are different than the characteristics of the corresponding physical processor **308**.

FIG. **4** depicts an illustrative cloud-based system architecture that may be used in accordance with one or more illustrative aspects described herein.

Referring to FIG. **4**, an example of a cloud computing environment (or cloud system) **400** that may be used to implement one or more illustrative aspects described herein is provided. Those of skill in the art will appreciate that the specific network architecture and data processing devices used may vary and are secondary to the functionality that they provide, as further described herein.

As seen in FIG. **4**, client computers **411-414** may communicate with a cloud management server **410** to access computing resources (e.g., host servers **403**, storage resources **404**, and network resources **405**) of the cloud system **400**.

Management server **410** may be implemented on one or more physical servers. The management server **410** may run, for example, CLOUDPLATFORM by Citrix Systems, Inc. of Ft. Lauderdale, Fla., or OPENSTACK, among others. Management server **410** may manage various computing resources, including cloud hardware and software resources, for example, host computer servers **403**, data storage devices **404**, and network elements **405**. The cloud hardware and software resources may include private and/or public components. For example, a cloud may be configured as a private cloud to be used by one or more particular customers or client computers **411-414** and/or over a private network. In other embodiments, public clouds or hybrid public-private clouds may be used by other customers over an open or hybrid networks.

Management server **410** may be configured to provide user interfaces through which cloud operators and cloud customers may interact with the cloud system **400**. For example, the management server **410** may provide a set of application programming interfaces (APIs) and/or one or more cloud operator console applications (e.g., web-based on standalone applications) with user interfaces configured to allow cloud operators to manage the cloud resources, configure the virtualization layer, manage customer accounts, and perform other cloud administration tasks. The management server **410** also may include a set of APIs and/or one or more customer console applications with user interfaces configured to receive cloud computing requests from end users via client computers **411-414**, for example, requests to create, modify, or destroy virtual machines within the cloud system **400**. Client computers **411-414** may connect to management server **410** via the Internet or other communication network, and may request access to one or more of the computing resources managed by management server **410**. In response to client requests, the management server **410** may include a resource manager configured to select and provision physical resources in the hardware layer of the cloud system **400** based on the client requests. For example, the management server **410** and additional components of the cloud system **400** may be configured to provision, create, and manage virtual machines and their operating environments (e.g., hypervisors, storage resources, services offered by the network elements, etc.) for customers at client computers **411-414**, over a network (e.g., the Internet), providing customers with computational resources, data storage services, networking capabilities, and computer platform and application support. Cloud system **400** also may be configured to provide various specific services, including security systems, development environments, user interfaces, and the like.

Certain client computers **411-414** may be related, for example, different client computers creating virtual machines on behalf of the same end user, or different users affiliated with the same company or organization. In other examples, certain client computers **411-414** may be unrelated, such as client computers associated with users affiliated with different companies or organizations. For unrelated client computers, information on the virtual machines or storage of any one client computer (or user) may be hidden from other client computers (or users).

Referring now to the physical hardware layer of a cloud computing environment **400**, availability zones **401-402** (or zones) may refer to a collocated set of physical computing resources. Zones may be geographically separated from other zones in the overall cloud of computing resources. For example, zone **401** may be a first cloud datacenter located in California, and zone **402** may be a second cloud datacenter located in Florida. Management sever **410** may be located at one of the availability zones **401-402**, or at a separate location. Each zone **401-402** may include an internal network that interfaces with devices that are outside of the zone, such as the management server **410**, through a gateway. End users of the cloud system **400** (e.g., client computers **411-414**) might or might not be aware of the distinctions between zones. For example, an end user may request the creation of a virtual machine having a specified amount of memory, processing power, and network capabilities. The management server **410** may respond to the user's request and may allocate the resources to create the virtual machine without the user knowing whether the virtual machine was created using resources from zone **401** or zone **402**. In other examples, the cloud system **400** may allow end users to request that virtual machines (or other cloud resources) are allocated in a specific zone or on specific resources **403-405** within a zone.

In this example, each zone **401-402** may include an arrangement of various physical hardware components (or computing resources) **403-405**, for example, physical hosting resources (or processing resources), physical network resources, physical storage resources, switches, and additional hardware resources that may be used to provide cloud computing services to customers. The physical hosting resources in a cloud zone **401-402** may include one or more host computer servers **403**, such as the virtualization servers **301** described above, which may be configured to create and host virtual machine instances. The physical storage resources in the cloud zone **401-402** may include storage devices **404** (e.g., solid state drives (SSDs), magnetic hard

disks, etc.) and other storage devices. The physical network resources in a cloud zone **401** or **402** may include one or more network elements **405** (e.g., network service providers) comprising hardware and/or software configured to provide a network service to cloud customers, such as firewalls, network address translators, load balancers, VPN gateways, DHCP routers, and the like.

The example cloud computing environment **400** shown in FIG. **4** also may include a virtualization layer (e.g., as shown in FIG. **1-3**) with additional hardware and/or software resources configured to create and manage virtual machines and provide other services to customers using the physical resources in the cloud. The virtualization layer may include hypervisors, as described above in FIG. **3**, along with other components to provide network virtualizations, storage virtualizations, etc. The virtualization layer may be as a separate layer from the physical resource layer, or may share some or all of the same hardware and/or software resources with the physical resource layer. For example, the virtualization layer may include a hypervisor installed in each of the virtualization servers, i.e. the host computer servers **403**, with the physical computing resources. Known cloud systems may alternatively be used, e.g., WINDOWS AZURE (Microsoft Corporation of Redmond Wash.), AMAZON EC2 (Amazon.com Inc. of Seattle, Wash.), IBM BLUE CLOUD (IBM Corporation of Armonk, N.Y.), or others.

Rendering a Web Application in a Cloud Service.

One or more aspects of the disclosure may incorporate, be embodied in, and/or be implemented using one or more of the computer system architecture, remote-access system architecture, virtualized (hypervisor) system architecture, and/or cloud-based system architecture discussed above in connection with FIGS. **1-4**.

FIG. **5** depicts an illustrative computing environment for rendering a web-based application in a cloud service in accordance with one or more illustrative aspects described herein.

Referring to FIG. **5**, a computing environment **500** is provided. The computing environment **500** may include a client computing device **510**, an ISV **530**, and a cloud service **540**.

The client computing device **510** may be a device similar to the computing device **201**, illustrated FIG. **2**, and/or the client computers **411-414**, illustrated in FIG. **4**. The client computing device **510** may be a device such as a PC, a mobile device, a laptop computer, a tablet, a smartphone, a PDA, a notebook, a set-top box, etc. One of ordinary skill in the art will understand that the client computing device **510** is not limited to the above-noted devices, but may include other devices known now or to be developed in the future. The client computing device **510** may include a processor **511**, a memory **513**, an input/output interface **515**, a display **517**, and a communication interface **519**.

The processor **511** may control overall operation of the client computing device **510** and its corresponding components.

The memory **513** may include a volatile and/or non-volatile memory. The memory **513** may store software and/or data relevant to at least one component of the client computing device **510**. The software may provide instructions to the processor **511** for configuring the client computing device **510** to perform various functions and methods described herein. The memory **513** may additionally include an operating system, application programs, databases, etc. The application programs stored in the memory **513** may include a local browser application **514** and a virtual machine receiver application **516**.

The local browser application **514** may provide web browsing functionality. The local browser application **514** may include a browser such as Microsoft Edge™, Microsoft Internet Explorer™, Google Chrome™, and Mozilla Firefox™. However, it should be understood by those of skill in the art, that the local browser application **514** is not limited thereto and may include other browsers.

The input/output interface **515** may be used as an interface for forwarding instructions or data, which are input into the client computing device **510** by a user or by another device. The input/output interface **515** may also be used as an interface for outputting instructions or data which are received from other components of the client computing device **510** or from another device.

The virtual machine receiver application **516** may be a thin-client or remote-display application for presenting display output generated by another application, such as by a remote browser application **545**, which is remotely executing on a host server, such as a remote server **542** in the cloud service **540**. The virtual machine receiver application **516** may provide the remotely generated output to a window of the local browser application **514** on the client computing device **510**. The remotely generated output may be a graphical user interface (GUI). The virtual machine receiver application **516** may be designed to present the GUI via the local browser application **514**, and record any user interactions occurring within the GUI. The virtual machine receiver application **516** may then transmit the user interactions occurring in the GUI back to the cloud service **540** to be forwarded to the remote server **542** and/or an ISV server **532** for processing. The virtual machine receiver application **516** may use, for example, an independent computing architecture (ICA) protocol, a remote desktop protocol (RDP), or the like.

The display **517** may be a device used to display various types of content, such as text, images, video, icons, etc.

The communication interface **519** may be used to establish communication between the client computing device **510** and other devices and elements of the computing environment **500**. For example, the communication interface **519** may establish a connection to the cloud service **540** via the network **520**.

The network **520** may include a LAN, a WAN, a MAN, a public network, a private network, a personal network, etc. The network **520** may be used to interconnect the client computing device **510** to the cloud service **540**.

The ISV **530** may be a computing system of a software vendor which develops and sells consumer and/or enterprise software or services. The ISV may sell or otherwise offer customers access to its software or services on a subscription or software as a service (SaaS) basis. Accordingly, the user of the client computing device **510** may subscribe to the ISV **530** for use of a particular software, such as a web application **543**, hosted by the ISV **530**. In accordance with an aspect of this disclosure, the ISV **530** may host a portion of a web application **543**, e.g., a rich internet application, on an ISV server **532** of the ISV **530**. The portion of the web application **543** hosted at the ISV server **532** may be a server-side or back-end portion of the web application **543***b*, such as a business layer and a data layer of the web application **543**. The business layer may support the underlying business logic, rules, and processing used by the web application **543**. The data layer may provide the web application **543** access to underlying data stores.

The cloud service **540** may be similar to the cloud system **400** illustrated in FIG. **400**. The cloud service **540** may host a remote server **542** and a policy manager service **544**. The

remote server **542** may be similar to the host servers **403** illustrated in FIG. **4**. The remote server **542** may further be a virtualization server, such as the virtualization server **301** illustrated in FIG. **3**, which may be configured to create and host virtual machine instances.

In accordance with an aspect of this disclosure, the remote server **542** may host at least a portion of the web application **543** and the remote browser application **545**.

That is, the ISV **530** may upload a client-side or front-end portion of the web application **543***a* to the remote server **542**. The front-end portion of the web application **543***a* may be a presentation layer of the web application **543**. The front-end portion of the web application **543***a*, hosted by the remote server **542** in the cloud service **540**, may communicate with the back-end portion of the web application **543***b*, hosted by the ISV server **532**. The front-end portion of the web application **543***a* and the back-end portion of the web application **543***b* may communicate with each other via a variety of different protocols and methods, including via Representational State Transfer (REST) API calls or Simple Object Access Protocol (SOAP) based calls.

The remote browser application **545** may be one or more instances of a web browser application, such as Microsoft Edge™, Microsoft Internet Explorer™, Google Chrome™, and Mozilla Firefox™ executing on the remote server **542**.

A session may be initiated at the remote server **542**, in response to a request by the client computing device **510** to execute the web application **543**, and the remote browser application **545** may be launched in the session. Accordingly, the front-end portion of the web application **543***a* may be executed and the remote server **542** may determine a browser which supports the web application **543** in which to render the output of the front-end portion of the web application **543***a*. The remote browser application **545** may use policy information maintained by the policy manager service **544** of the cloud service **540** to determine the supported browser. The remote browser application **545** may execute the front-end of the web application **543***a* in the determined remote browser application **545**. The output, such as a GUI, rendered by the remote browser application **545** is transmitted to the virtual machine receiver application **516** in the client computing device **510** to be presented in a window of the local browser application **514** executing in the client computing device **510**.

Accordingly, the remote browser application **545** may be used seamlessly by the client computing device **510** to provide access to natively unsupported web applications and content. Use of the remote browser application **545** by the client computing device **510** may also enhance and/or otherwise provide improved security at the client computing device **510**.

The policy manager service **544** may be a server providing device policy manager services, application policy manager services, data policy manager services, and the like. That is, the policy manager service **544** may manage policies defined by the ISV **530**, the cloud service **540**, or by an enterprise (not shown) associated with the client computing device **510** for devices communicating with the cloud service **540**, applications operating on the cloud service **540**, and data residing on or otherwise associated with the ISV **530**, the cloud service **540**, or an enterprise associated with the client computing device **510**. For example, in accordance with an aspect of this disclosure, the policy manager service **544** may maintain policy information relating to a specific version of the front-end portion of the web application **543***a* required by the back-end portion of the web application **543***b* or by other resources used by the front-end portion of the web application **543***a*. In accordance with another aspect of this disclosure, the policy manager service **544** may maintain policy information relating to a browser application which is compatible with the front-end portion of the web application **543***a*. The policy information maintained by the policy manager service **544** may be used by the client computer device **510**, the ISV server **532**, or the remote server **542**. While the policy manager service **544** is illustrated as being located at the cloud service **540**, the policy manager service **544** may alternatively be located at the ISV **530**.

The ISV **530** may be connected to the cloud service **540** via a gateway **500**. For example, the gateway **550** may be a NetScaler gateway, a cloud service gateway, a VPN gateway, etc. The gateway **500** may serve as a secure channel for communicating between the cloud service **540** and the ISV **530**. Alternatively, the cloud service **540** and the ISV **330** may communicate via a VPN.

FIG. **6** depicts an illustrative event sequence for rendering a web-based application in a cloud service in accordance with one or more illustrative aspects described herein.

Referring to FIG. **6**, the sequence of events described herein may be executed by the computing environment illustrated in FIG. **5**.

First, at step **601**, the client computing device **510** may receive a request to execute the web application **543** when, for example, a user of the client computing device **510** enters a uniform resource locator (URL) into an address field of the local browser application **514** or when another application executing on the client computing device **510**, or executing externally, attempts to access the local browser application **514** to execute the web application **543**. In this case, the client computing device **510** may determine to send the request to execute the web application **543** to the remote server **542** which hosts at least the front-end portion of the web application **543***a*. The client computing device **510** may make the determination to send the request to the remote server **542** based on policy information. The policy information may be obtained from the policy manager service **544** in the cloud service **540** via push or pull-based mechanisms. Alternatively, the policy manager services **544** may be located at the ISV **530**. The client computing device **510** may store the policy information in the memory **513** of the client computing device **510**. As another alternative, the policy information may be pre-stored in the memory **513** of the client computing device **510** and may be directly accessed by the client computing device **510** therefrom.

The client computing device **510** may determine to send the request to the remote server **542** when the policy information indicates that the requested web application **543** is not supported at the client computing device **510**. The policy information may indicate that the web application **543** is not supported at the client computing device **510** for a variety of reasons. For example, when the local browser application **514** does not support a deprecated web application **543** or a deprecated feature of the web application **543** the policy information may indicate that the web application **543** is not supported—such as when the local browser application **514** does not support a Microsoft Silverlight™ application, Adobe Flash™ content, or Oracle Java™ browser plugins due to deprecation. As another example, when a specific version of the front-end portion of the web application **543** is required by the back-end portion of the web application **543***b*, the policy information may indicate that the web application **543** is not supported. One of ordinary skill in the art would recognize that the policy information may indicate that the web application is not

supported at the client computing devices **510** for reasons other than those listed herein. The policy information may indicate the web applications **543** which are not supported at the client computing device **510** by maintaining a list of URLs that are to be accessed remotely instead of locally. The policy information may further indicate additional information about the web applications **543** which are not supported at the client computing device **510**.

Next, at step **602**, the client computing device **510** may authenticate the user of the client computing device **510**. The client computing device **510** may authenticate the user using one or more of a variety of methods—such as validating a username and password entered by the user, biometric input provided by the user, and/or other input provided by the user. The client computing device **510** may cache one or more authentication credentials linked to and/or otherwise associated with the user. In caching the one or more authentication credentials associated with the user, the client computing device **510** may store in a keychain and/or otherwise cache one or more single sign-on (SSO) credentials linked to a user account of the cloud service **540** associated with the user. The SSO credentials may be usable by the client computing device **510** to enable the client computing device **510** to login to the cloud service **540** to access the remote server **542** and request the remote server **542** to execute the web application **543**. The cloud service **540** may establish a connection with the ISV **530** via the gateway **550** and may use the SSO credentials to access the user's account at the ISV **530**. The ISV **530** may alternatively require a separate authentication process for access thereto.

Next, at step **603**, after the client computing device **510** determines that web application **543** is not supported at the client computing device **510** and the user has been successfully authenticated, the client computing device **510** may send, via the communication interface **519**, a request to the remote server **542** for the remote browser **542** to execute the web application **543** instead of the client computing device **510** executing the web application **543**. The request may include a parameterized URL, supplying for example, the requested web application **543**, a path to the remote browser application **545**, commands for executing the remote browser application **545** in a specific mode, e.g., in a kiosk mode, and any other necessary data. The request may further include received policy information.

Next, at step **604**, in response to receiving the request to execute the web application **543**, the client computing device **510** may control the remote server **542** to initiate, at the remote server **542**, a session linked to the user account of the user of the client computing device **510**.

The client computing device **510** may then control the remote server **542** to determine a specific version of the front-end portion of the web application **543***a* and a specific instance of the remote browser application **545** in which to execute the web application **543**. The determinations may be made based on policy information.

The remote server **542** may obtain the policy information from the policy manager service **544** in the cloud service **540**. Alternatively, the policy manager service **544** may be located at the ISV **530** and, in this case, the remote server **542** may obtain the policy information therefrom. Alternatively still, the client computing device **510** may store the policy information in a memory **513** of the client computing device **510** and may transmit the policy information to the remote server **542** with the request to execute the web application **543**. The remote server **542** may store the policy information in a memory of the remote server **542**.

The client computing device **510** may then control the remote server **542** to launch an instance of the remote browser application **545** in the remote session. The client computing device **510** may control the remote server **542** to launch an instance of a specific remote browser application **545** (such as Microsoft Internet Explorer™, Google Chrome™, etc.) which is determined to be compatible with the first portion of the web application **543***a*. The remote server **542** may determine the specific remote browser application **545** to launch based on policy information. The policy information may be obtained as noted above.

Next, at step **605**, the client computing device **510** may control the remote server **542** to execute the web application **543** by executing the determined front-end portion of the web application **543***a* in the determined remote browser application **545**.

Next, at step **606**, in executing the web application **543**, the client computing device **510** may control the remote server **542** to connect ISV server **532** hosting the back-end portion of the web application **543***b*. The front-end portion of the web application **543***a* may send a message to the back-end portion of the web application **543***b* requesting processing and/or content. The back-end portion of the web application **543***b* may perform the processing and may send a message, including the content, to the front-end portion of the web application **543***a*. The messages may be sent via a variety of different protocols and methods, including via Representational State Transfer (REST) API calls or Simple Object Access Protocol (SOAP) based calls.

Next, at step **607**, in executing the web application **543**, the client computing device **510** may further control the remote server **542** to generate, using the front-end portion of the web application **543***a*, a GUI based on the content sent from the back-end portion of the web application **543***b*. The remote server **542** may render the GUI, together with the content, in the remote browser application **545** on the remote server **542**.

Next, at step **608**, the client computing device **510** may control the remote server **542** to transmit, to the client computing device **510**, the graphics associated with the GUI (together with any content displayed in the GUI) output to the remote browser application **545**. The GUI may be, for example, a static page, a dynamic page, an animation, or the like.

Next, at step **609**, in response to receiving the GUI graphics, the client computing device **510** may present the received GUI graphics to the local browser application **514** executing on the client computing device **510** for display on a window of the local browser application **514**. The GUI displayed in the local browser application **514** may appear the same as or similar to the GUI rendered in the remote browser application **545**. For example, the local browser application **514** may display user interface elements, controls, and/or other content associated with the local browser application **514** (e.g., tab listing, back button, forward button, and/or other elements) as well as the GUI rendered at the remote browser application **545** and transmitted to the client computing device **510**. In this way the web application **543**, which is unsupported by the client computing device **510**, is able to be rendered in the local browser application **514** using the GUI generated at the remote server **542** by the remote browser application **545**.

Next, at step **610**, the client computing device **510** may track browsing activity and record interactions with the GUI displayed in the local browser application **514**. For example, the client computing device **510** may track browsing activity by maintaining a stack of browsing transitions associated

with browsing activity. As such, the client computing device **510** may track and/or store information identifying pages accessed and/or transitions between pages, including local browsing activity in the local browser application **514** and remote browsing activity in the remote browser application **545**. The client computing device **510** may maintain such a stack of browsing transitions to enable backward and/or forward navigation functionality, history tracking functionality, and/or other functionality in the local browser application **514** and/or in the remote browser application **545**. Alternatively or additionally, such a stack of browsing transitions may be maintained on the remote server **542**.

The client computing device **510** may record interactions with the GUI when an input is received in the GUI displayed in the local browser application **514**. Such input may, for example, include a selection of a link included in the GUI displayed in the local browser application **514**, an interaction with a form or other control included in the GUI displayed in the local browser application **514**, an interaction with some other element included in the GUI displayed in the local browser application **514**, etc. Accordingly, when such an input interacting with the GUI displayed in the local browser application **514** is received, the client computing device **510** may update the stack of browsing transitions based on the received input. For example, if the input includes the selection of a link and/or a transition to a new page associated with the link, the client computing device **510** may update the stack of browsing transitions to include information identifying the selection of the link and/or the transition to the new page associated with the link.

Next, at step **611**, the client computing device **510** may send, to remote server **542**, via the communication interface **519**, the input interacting with the GUI displayed in the local browser application **514**.

Next, at step **612**, the client computing device **510** may control the remote server **542** to re-execute the web application **543** based on the received input interacting with the GUI displayed in the local browser application **514**. Step **612** may be similar to step **605**.

Next, at step **613**, in re-executing the web application **543**, the client computing device **510** may control the remote server **542** to connect to the ISV server **532** hosting the back-end portion of the web application **543***b* to obtain any new content associated with the web application **543** based on the received input. To this end, the front-end portion of the web application **543***a* may send a message to the back-end portion of the web application **543***b* requesting processing and/or new content based on the received input. The back-end portion of the web application **543***b* may perform the processing and may send a message, including the new content, to the front-end portion of the web application **543***a*. Step **613** may be similar to step **606**.

Next, at step **614**, in executing the web application **543**, the client computing device **510** may further control the remote server **542** to generate, using the front-end portion of the web application **543***a*, an updated GUI based on the new content sent from the back-end portion of the web application **543***b*. The remote server **542** may render the updated GUI, together with the new content, in the remote browser application **545** on the remote server **542**. Step **614** may be similar to step **607**.

Next, at step **615**, the client computing device **510** may control the remote server **542** to transmit, to the client computing device **510**, the graphics associated with the updated GUI (together with any new content displayed in the GUI) output to remote browser application **545**. The updated GUI may be, for example, a static page, a dynamic page, an animation, or the like. Step **615** may be similar to step **608**.

Next, at step **616**, in response to receiving the updated GUI, the client computing device **510** may present the received updated GUI graphics to the local browser application **514** executing on the client computing device **510** for display on a window of the local browser application **514**. Step **616** may be similar to step **609**.

The client computing device **510** may repeat steps **610**-**616** until the local browser application **514** is terminated or no further inputs are received in the GUI displayed in the local browser application **514**.

FIGS. **7**A-**7**B depict a flowchart of an illustrative method of a client computing device for rendering a web-based application in a cloud service in accordance with one or more illustrative aspects described herein.

Referring to FIGS. **7**A-**7**B, the method described herein relates to a method of a client computing device and may be executed by the computing environment illustrated in FIG. **5**.

At step **702**, the client computing device **510** may receive a request to execute the web application **543** in the local browser application **514**. The request may be initiated in the local browser application **514** by a user or by another application executing on the client computing device **510**, or executing externally, and attempting to access the local browser application **514** to execute the web application **543**.

At step **704**, the client computing device **510** may obtain policy information related to the requested web application **543**. The policy information may be obtained in the manner described with respect to FIG. **6**.

At step **706**, based on the obtained policy information, the client computing device **510** may determine whether to execute the web application **543** locally, by the client computing device **510**, or remotely, by the remote server **542** hosting at least a portion of the web application **543**. The client computing device **510** may determine to execute the web application **543** remotely, when the policy information indicates that the requested web application **543** is not supported at the client computing device **510**. The policy information may indicate that the web application **543** is not supported at the client computing device **510** in the manner described with respect to FIG. **6**.

If the client computing device **510** determines not to execute the web application **543** remotely, then at step **708**, the client computing device **510** executes the web application **543** in the local browser application **514** at the client computing device **510**.

Otherwise, if the client computing device **510** determines to execute the web application **543** at the remote server **542**, then at step **710**, the client computing device **510** may authenticate the user of the client computing device **510** for access to the cloud service **540** and/or the ISV **530**. The user may be authenticated in the manner described with respect to FIG. **6**.

At step **712**, in response to successful authentication of the user, the client computing device **510** may send, via the communication interface **519**, a request to the remote server **542**, which hosts the front-end portion of the web application **543***a*, to execute the web application **543**.

At step **714**, in response to the request to the remote server **542** to execute the web application **543**, the client computing device **510** may receive, from the remote server **542**, graphics associated with a GUI of the web application **543** which has been executed and rendered in the remote browser application **545** on the remote server **542**.

At step **716**, in response to receiving the GUI graphics, the client computing device **510** may present the received GUI graphics to the local browser application **514** executing on the client computing device **510** for display on a window of the local browser application **514**.

At step **718**, the client computing device **510** may track browsing activity and record interactions with the GUI displayed in the local browser application **514**. For example, the client computing device **510** may track browsing activity by maintaining a stack of browsing transitions associated with browsing activity and may record input interactions, such as the selection of a link or input of data, received in the GUI displayed in the local browser application **514**.

At step **720**, the client computing device **510** may send, to the remote server **542**, via the communication interface **519**, the input interacting with the GUI displayed in the local browser application **514**.

At step **722**, in response to sending the inputs interacting with the GUI to the remote server **542**, the client computing device **510** may receive, from the remote server **542**, graphics associated with an updated GUI of the web application **543**, which has been re-executed in the remote browser application **545** based on the sent inputs and then output again to remote browser application **545**.

At step **724**, in response to receiving the updated GUI graphics, the client computing device **510** may present the received updated GUI graphics to the local browser application **514** executing on the client computing device **510** for display on a window of the local browser application **514**.

The client computing device **510** may repeatedly execute steps **718**-**724** until the local browser application **514** is terminated or no further input is received in the GUI graphics in the local browser application **514**.

In this way the web application **543**, which is unsupported by the client computing device **510**, is able to be rendered in the local browser application **514** by executing the web application at the remote server **542** and using a GUI generated at the remote server **542** by the remote browser application **545** for display in the local browser application **514**.

FIGS. **8**A-**8**C depict a flowchart of an illustrative method of a remote server for rendering a web-based application in a cloud service in accordance with one or more illustrative aspects described herein.

Referring to FIGS. **8**A-**8**C, the method described herein relates to a method of a remote server and may be executed by the computing environment illustrated in FIG. **5**.

At step **802**, the remote server **542** may receive, from the client computing device **510**, a request to execute the web application **543**, where at least the front-end portion of the web application **543***a* is hosted on the remote server **542**.

At step **804**, the remote server **542** may establish a connection with the client computing device **510** upon successfully authenticating a user of the client computing device **510**.

At step **806**, in response to receiving the request to execute the web application **543**, the remote server **542** may initiate a session linked to the user account of the user of the client computing device **510**.

At step **808**, the remote server **542** may determine a specific version of the front-end portion of the web application **543***a* to execute based on obtained policy information. The remote server **542** may obtain the policy information in the manner described with respect to FIG. **6**.

At step **810**, the remote server **542** may launch an instance of a specific remote browser application **545** (such as Microsoft Internet Explorer™, Google Chrome™, etc.) which is determined to be compatible with the first portion of the web application **543***a*, based on the policy information.

At step **812**, the remote server **542** may execute the web application **543** by executing the determined front-end portion of the web application **543** in the determined remote browser application **545**.

At step **814**, the remote server **542** may connect to the ISV server **532** hosting the back-end portion of the web application **543***b*. The front-end portion of the web application **543***a* may send a message to the back-end portion of the web application **543***b* requesting processing and/or content.

At step **816**, the remote server **542** may receive a message, including the content, from the back-end portion of the web application **543***b*.

At step **818**, the remote server **542** may generate, using the front-end portion of the web application **543***a*, a GUI based on the content received from the back-end portion of the web application **543***b*. The remote server **542** may render the GUI, together with the content, in the remote browser application **545**.

At step **820**, the remote server **542** may transmit, to the client computing device **510**, the graphics associated with the GUI (together with any content displayed in the GUI) output to the remote browser application **545**.

At step **822**, the remote server **542** may receive, from the client computing device **510**, input interacting with the GUI displayed in the local browser application **514**.

At step **824**, the remote server **542** may re-execute the web application **543** based on the received input interacting with the GUI displayed in the local browser application **514**.

At step **826**, the remote server **542** may connect to the ISV server **532** hosting the back-end portion of the web application **543***b* and the front-end portion of the web application **543***a* may send a message to the back-end portion of the web application **543***b* requesting processing and/or new content based on the received input.

At step **828**, in response, the back-end portion of the web application **543***b* may send the front-end portion of the web application **543***a* a message including the new content.

At step **830**, the remote server **542** may generate, using the front-end portion of the web application **543***a*, an updated GUI based on the new content received from the back-end portion of the web application **543***b*. The remote server **542** may render the updated GUI, together with the new content, in the remote browser application **545**.

At step **832**, the remote server **542** may transmit, to the client computing device **510**, the graphics associated with the updated GUI (together with any new content displayed in the GUI) output to remote browser application **545**.

Accordingly, various aspect of the disclosure describe novel ways of rendering a web application virtually by hosting at least a part of the web application in a cloud service and executing the web application in the cloud for access by a remote client device. The part of the web application that is hosted in the cloud may be a front end portion, while the remaining sensitive parts, such as the back-end portion, may be located at a separate secure location such as an ISV. This approach provides the flexibility to choose where to host the various parts of a web application without having to create additional network access rules and without having to deploy VPN solutions. Further, improved performance can be achieved in various geographical locations by hosting the front end portion of the web application in a content delivery network (CDN). Alternatively, the geographic location of the cloud service where the web application is rendered can be chosen to be

close to the location of where the back-end portion of the web application is hosted for improved throughput. Further, as the deprecation of certain software forces users to access affected web applications using only certain web browsers which still support the deprecated web applications, according to aspects described herein, a user may access the same deprecated web application via any local browser by having the web application executed virtually—in a remote browser hosted in a cloud service. Accordingly, issues of application and software incompatibility may be solved.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are provided as some example implementations of the following claims.

What is claimed is:

**1**. A method, the method comprising:

receiving, by a virtual server and from a client device, a request to execute a web application in a virtualized browser application hosted by the virtual server, wherein a front-end portion of the web application, configured to output a graphical user interface of the web application to the virtualized browser application, is installed at the virtual server and wherein a back-end portion of the web application, configured to perform business logic and processing of the web application, is installed at a second server different from the virtual server, and wherein the web application is different from the virtualized browser application;

determining a required version of the web application to execute in the virtualized browser application;

executing, at the virtual server and in the virtualized browser application, the required version of the web application, in response to the request by the client device; and

sending, to the client device and for display in a client browser application executing at the client device, a user interface corresponding to the graphical user interface of the required version of the web application executing in the virtualized browser application.

**2**. The method of claim **1**, wherein the front-end portion of the web application communicates with the back-end portion of the web application via application program interface (API) calls.

**3**. The method of claim **2**, wherein the API calls comprise Representational State Transfer (REST) calls or Simple Object Access Protocol (SOAP) based calls.

**4**. The method of claim **1**, wherein executing the required version of the web application comprises:

initiating a session at the virtual server;

launching the virtualized browser application in the session;

executing, in the virtualized browser application, the front-end portion of the required version of the web application; and

generating, based on the graphical user interface output by the front-end portion in the virtualized browser application, the user interface of the required version of the web application to send to the client device.

**5**. The method of claim **1**, further comprising:

receiving policy information;

determining one of a plurality of virtualized browser applications hosted by the virtual server to launch, based on the received policy information indicating a virtualized browser application compatible with the required version of the web application; and

launching the determined virtualized browser application.

**6**. The method of claim **1**, wherein determining the required version of the web application to execute comprises:

receiving policy information; and

determining, based on the received policy information, a required version of the front-end portion of the web application to execute.

**7**. The method of claim **1**, further comprising:

receiving, from the client device, first input data input into the user interface of the required version of the web application displayed in the client browser application executing at the client device;

in response to receiving the first input data, re-executing, in the virtualized browser application and based on the first input data, the front-end portion of the required version of the web application, wherein re-executing the front-end portion comprises;

sending, to the second server via one or more API calls, the first input data;

receiving, from the second server via one or more API calls, content based on the first input data; and

updating, based on the received content, the graphical user interface of the front-end portion of the required version of the web application executing in the virtualized browser application; and

sending, to the client device, an updated user interface corresponding to the updated graphical user interface of the required version of the web application executing in the virtualized browser application.

**8**. The method of claim **1**, wherein the virtual server is hosted by a cloud service.

**9**. The method of claim **1**, wherein the virtual server is hosted by a content delivery network.

**10**. A server, comprising:

a processor;

a communication interface coupled to the processor; and

a memory storing a virtualized browser application and at least a front-end portion of a web application, wherein the front-end portion is configured to output a graphical user interface of the web application; and

wherein the processor is configured to:

receive, from a client device and via the communication interface, a request to execute the web application in the virtualized browser application, wherein the web application is different from the virtualized browser application;

determine a required version of the web application to execute in the virtualized browser application;

execute, in the virtualized browser application, the required version of the web application; and

send, to the client device, via the communication interface, and for display in a client browser application executing at the client device, a user interface corresponding to the graphical user interface of the required version of the web application executing in the virtualized browser application,

wherein a back-end portion of the web application, configured to perform business logic and processing of the web application, is installed at a second server.

**11**. The server of claim **10**, wherein the processor is further configured to execute the required version of the web application by:

initiating a session;

launching the virtualized browser application in the session;

executing, in the virtualized browser application, the front-end portion of the required version of the web application; and

generating, based on the graphical user interface output by the front-end portion in the virtualized browser application, the user interface of the required version of the web application to send to the client device.

**12**. The server of claim **10**, wherein the processor is further configured to:

receive policy information;

determine one of a plurality of virtualized browser applications hosted by the server to launch based on the received policy information indicating a virtualized browser application compatible with the required version of the web application; and

launch the determined virtualized browser application.

**13**. The server of claim **10**, wherein the processor is further configured to determine the required version of the web application to execute by:

receiving policy information; and

determining, based on the received policy information, a required version of the front-end portion of the web application to execute.

**14**. The server of claim **10**, wherein the processor is further configured to:

receive, from the client device, first input data input into the user interface of the required version of the web application displayed in the client browser application executing at the client device;

in response to receiving the first input data, re-execute, in the virtualized browser application and based on the first input data, the front-end portion of the required version of the web application, wherein re-executing the front-end portion comprises:

sending, to the second server via one or more application program interface (API) calls, the first input data;

receiving, from the second server via one or more API calls, content based on the first input data; and

updating, based on the received content, the graphical user interface of the front-end portion of the required version of the web application executing in the virtualized browser application; and

send, to the client device, an updated user interface corresponding to the updated graphical user interface of the required version of the web application executing in the virtualized browser application.

**15**. A non-transitory, computer-readable storage medium, having instructions stored thereon, which when executed by a client device, configure the client device to perform:

outputting a client browser application for display in a display of the client device;

receiving, via the client browser application, a first request to execute a web application;

in response to the first request, sending, to a virtual server, a second request to execute a virtualized web application, corresponding to the requested web application, in a virtualized browser application hosted by the virtual server, wherein the second request includes policy information indicating a required version of the virtualized web application to execute in the virtualized browser application, and wherein the virtualized web application is different from the virtualized browser application;

in response to the second request, receiving, from the virtual server, a user interface corresponding to a graphical user interface of the required version of the virtualized web application executing in the virtualized browser application, wherein the graphical user interface is output by a front-end portion of the required version of the virtualized web application which is installed at the virtual server and which communicates with a back-end portion of virtualized web application, installed at a second server different from the virtual server, to control the back-end portion to perform business logic and processing functions associated with the virtualized web application; and

outputting, to the client browser application, the user interface of the required version of the virtualized web application.

**16**. The storage medium of claim **15**, wherein the front-end portion of the virtualized web application communicates with the back-end portion of the virtualized web application via application program interface (API) calls.

**17**. The storage medium of claim **15**, wherein the user interface of the required version of the virtualized web application is generated based on the graphical user interface output by the front-end portion in the virtualized browser application hosted by the virtual server, and

wherein the virtualized browser application is executed in a virtual session initiated at the virtual server.

**18**. The storage medium of claim **15**, wherein the second request to execute the virtualized web application is sent in response to detecting a failure by the client device to launch the requested web application.

**19**. The storage medium of claim **15**, wherein the instructions, which when executed by the client device, further configure the client device to perform:

receiving the policy information,

wherein the second request to execute the virtualized web application is sent in response to identifying, from the received policy information, at least one of: information indicating that the requested web application is unsupported at the client device and information indicating that a specific version of the requested web application is required.

**20**. The storage medium of claim **15**, wherein the instructions, which when executed by the client device, further configure the client device to perform:

receiving a first input in the user interface of the required version of the virtualized web application output to the client browser application;

in response to receiving the first input, sending, to the virtual server, the first input;

receiving, from the virtual server, an updated user interface corresponding to the graphical user interface of the required version of the virtualized web application executing in the virtualized browser application and updated based on the first input; and

outputting, to the client browser application, the updated user interface of the required version of the virtualized web application.

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